Global obesity: trends, risk factors and policy implications

Vasanti S. Malik, Walter C. Willett and Frank B. Hu

Abstract | The worldwide increase in obesity and related chronic diseases has largely been driven by global trade liberalization, economic growth and rapid urbanization. These factors continue to fuel dramatic changes in living environments, diets and lifestyles in ways that promote positive energy balance. Nutritional transitions in low-income and middle-income countries are typically characterized by increases in the consumption of animal fat and protein, refined grains, and added sugar. This change is coupled with reductions in physical activity owing to more mechanized and technologically driven lifestyles. Given the high costs of obesity and comorbidities in terms of health-care expenditure and quality of life, prevention strategies are paramount, particularly in low-income and middle-income countries that must manage coexisting infectious diseases and undernutrition in addition to the obesity epidemic. As countries become increasingly urbanized, undernutrition and obesity can exist side by side within the same country, community or household, which is a particular challenge for health systems with limited resources. Owing to the scope and complexity of the obesity epidemic, prevention strategies and policies across multiple levels are needed in order to have a measurable effect. Changes should include high-level global policies from the international community and coordinated efforts by governments, organizations, communities and individuals to positively influence behavioural change.

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Introduction

Once considered a problem only in the USA and other high-income countries of the Western world, obesity (BMI ≥30 kg/m^2) has become a major contributor to the global burden of disease.[1,2] Excessive adiposity is an important risk factor for morbidity and mortality from type 2 diabetes mellitus (T2DM), cardiovascular diseases and some cancers.[3–5] The worldwide increase in the incidence of obesity and related chronic diseases has largely been driven by global trade liberalization, economic growth and rapid urbanization, which continue to fuel dramatic changes in living environments as well as in diets and lifestyles that promote positive energy balance.[6–9] Positive energy balance occurs when an individual's caloric intake exceeds their energy expenditure, leading to weight gain. Although globalization has clearly led to substantial improvements in quality of life and food security, and a reduction in the level of poverty for many countries, unintended consequences of globalization have led to an increased consumption of sugar-sweetened beverages and foods that are low in nutritional value and high in energy. Combined with reductions in physical activity, these factors are driving the global obesity epidemic.[9]

The costs of obesity and its associated comorbidities are staggering, both in terms of health-care expenditure and quality of life, underscoring the importance of implementing prevention strategies. In the USA, provision of care to patients with T2DM and related sequelae led to US$113 billion in direct medical costs in 2007,[10] and medical costs attributable to obesity were estimated at US$147 billion per year in 2008.[11] Low-income and middle-income countries (LMCs) currently carry the majority of the obesity and chronic disease burden, and are predicted to continue to do so in future decades.[12] LMCs include low-income countries such as those in Sub-Saharan Africa, lower-middle-income countries such as India and parts of South-East Asia, and upper-middle-income countries such as China and most of South America.[13] The costs related to the treatment of obesity and its various comorbidities will be particularly detrimental to public health and the economy of LMCs. Many of these countries have limited health-care resources and their infrastructures are not sufficient to manage escalating rates of these conditions alongside the coexisting burdens of undernutrition and infectious diseases.

Undernutrition and obesity can exist side by side within a country, community or household, which poses a particular challenge for implementing nutrition-policy strategies. Within a given country, obesity and related conditions tend to be more prevalent in urban areas than in rural areas. People with low incomes living in a highly urbanized LMC, such as Brazil, have a higher risk of obesity than wealthy individuals in the same country owing to widespread access to cheap food that is high in

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Key points

- Although globalization has resulted in substantial improvements in quality of life and food security, as well as reductions in poverty, unintended consequences of globalization are also driving the obesity epidemic
- Global trade liberalization and increases in income and urbanization have created obesogenic environments that promote nutritional transitions and reductions in physical activity, resulting in positive energy balance
- Dietary changes leading to positive energy balance are characterized by increases in the consumption of animal products, refined grains and sugar
- Dietary changes are driven by the increased availability of low-cost food and drinks, which are often low in nutritional value and high in energy and sugar
- Strategies to address the global obesity epidemic require sustained, population-wide interventions and policy recommendations designed to improve diet and increase physical activity using a multilevel systems approach
- Combating obesity requires coordinated efforts from the international community, governments, industry, health-care systems, schools, urban planners, agricultural and service sectors, the media, communities and individuals

energy and low in nutritional quality, and a sedentary lifestyle.[14] However, some people with low incomes in the same country, such as those who have moved from rural to urban areas and lost the ability to grow their own food, are dependent on a cash market for food and this situation could lead to undernutrition.[14] Children aged <5 years are most vulnerable to undernutrition owing to requirements during growth, which might explain the paradox of 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 but provide excess calories to older children and adults, promoting weight gain.

People in wealthy segments of the population have a lower risk of obesity than those in low-income segments, possibly owing to access to a high level of health education, sufficient income to purchase healthy foods, adequate time for leisure and physical activities, and access to quality health care.[14] Increased household health-care expenditure could also exacerbate poverty, by trapping poor households in cycles of debt and illness, further perpetuating health and economic inequalities in LMCs.[15] An estimated US$84 billion in economic production could be lost in LMCs as a result of obesity-related chronic diseases between 2006 and 2015, if the epidemic is unabated.[16]

The changes that are needed to reverse the obesity epidemic are likely to require sustained interventions and numerous policy recommendations from the international community, governments and organizations that target diet, lifestyle and environmental risk factors. Although many putative causes of the obesity epidemic exist, in this Review we discuss the effect of globalization on global trends in obesity prevalence through changes in macro-level factors, which are factors that influence individual (micro-level) behaviours; specifically, global trade liberalization, economic growth and urbanization. We discuss global changes in diet, physical activity and sociocultural norms that have occurred over the past three to four decades. We also review population-based interventions from several countries and make broad policy recommendations for obesity and chronic disease prevention at the global level.

Global burden of obesity

National survey data show that the obesity epidemic began in the USA over 40 years ago, with the estimated prevalence having more than doubled in the USA from 1980 to 2010 and worldwide from 1980 to 2008.[1,17] Globally, between 1980 and 2008, obesity prevalence rose from 4.8% to 9.8% in men and from 7.9% to 13.8% in women.[1] In the USA alone in 2009–2010, 35.5% of men and 35.8% of women had obesity.[17] Although overall estimates of obesity prevalence in the total population of the USA have steadied since 2003, they remain alarmingly high and have continued to rise in men, non-Hispanic black women and Mexican–American women.[17]

The global effect of the obesity epidemic was formally recognized by the WHO during a special obesity consultation in 1997.[18] In the past 15 years, a large body of evidence has been accumulated documenting the temporal increases in the prevalence of obesity across the globe (Figure 1). These figures show that an estimated 500 million adults had obesity in 2008, which represents 10–14% of the world's population. According to these data, the sex-specific prevalence of obesity was highest in North America (men: 29.2%) and in southern Africa (women: 36.5%).[1] Obesity prevalence >30% was also observed in women living in North America, Latin America, North Africa and the Middle East.

Over the next two decades, the largest proportional increase in the number of adults who are overweight or have obesity is expected to occur in LMCs, where estimates range from increases of 62–205% and 71–263% for overweight and obesity, respectively.[12] The application of Asian-specific criteria for the diagnosis of overweight and obesity, in which a lower BMI cut-off is used than in criteria for individuals from Western countries, could lead to even higher estimates for some LMCs.[19] An important point to note is that the burden of obesity will continue to increase as a result of population growth even without an increase in prevalence. Additionally, in a number of LMCs, the increase in the prevalence of obesity has occurred rapidly.[20] In fact, in many LMCs, 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.[21] A number of countries must, therefore, manage dual burdens of obesity and related chronic diseases, while still dealing with the problems of underweight and undernutrition. These points mean that important considerations are required when developing and implementing nutrition policies in LMCs.

Childhood obesity has emerged as one of the most serious public-health challenges of the 21st century,[22] given the reduction in quality of life and the associated health complications of this condition.[8,23] Childhood obesity has been shown to continue into adulthood,[24] increasing the risk of chronic diseases and disability later in life. According to the International Diabetes Federation and the WHO, tackling childhood obesity is a highly effective way of preventing the future development of T2DM. However, malnutrition and stunted growth

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often exist in children in LMCs.[2] Eliminating undernutrition without increasing obesity is critical, but poses a serious challenge.[2] Although the prevalence of obesity is higher in adults than in children, the increase in the incidence of obesity among children has occurred more rapidly than that among adults in some countries, such as the USA, Brazil and China.[25] The worldwide prevalence of childhood overweight and obesity increased from 4.2% to 6.7% between 1990 and 2010.[26] This increase means that an estimated 43 million children were overweight or had obesity in 2010, of whom 35 million live in LMCs.[26] The total number of children worldwide who are overweight or have obesity is expected to reach 60 million (9.1%) by 2020 if trends are not reversed.[26]

Globalization: macro-level drivers

Globalization is defined by the Board on Global Health of the Institute of Medicine as "the spread of knowledge and science, telecommunications and other information technologies, and cultural and behavioural adaptations".[9] Globalization, in a broader sense, also encompasses free movement of money, increased direct foreign investment, expansion of marketing systems, as well as wide and homogeneous consumer choices.[9] Collectively, these changes have profound effects on food availability and lifestyle habits. Although globalization has clearly led to substantial improvements in quality of life and food security, as well as reductions in poverty for many people through social and economic modernization, the unintended consequences of globalization are nutritional transitions and changes in lifestyle and living environments that are driving the global obesity epidemic (Figure 2). These changes are largely mediated through the macro-level factors of global trade liberalization, increased *per capita* income and socioeconomic status, as well as increased urbanization.

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. These policies have altered the food supply and had direct effects on the obesity epidemic, contributing to nutritional transition and changing food choice and availability. 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 through expansion of multinational food companies and fast-food chains.[7] For example, in 1998, transnational food companies based in the USA invested US$5.7 billion in establishing outlets globally.[27] Analysis shows that LMCs that enter free-trade agreements with the USA have a 63.4% (95% CI 24.0–103.3%) higher level of sugar-sweetened beverage consumption *per capita* than those that do not, after adjusting for a given country's level of Gross Domestic Product (GDP) *per capita* and urbanization.[28]

In the USA, the farm bill—a major piece of agricultural legislation—has had a profound effect on food cost and availability through crop subsidy and food assistance

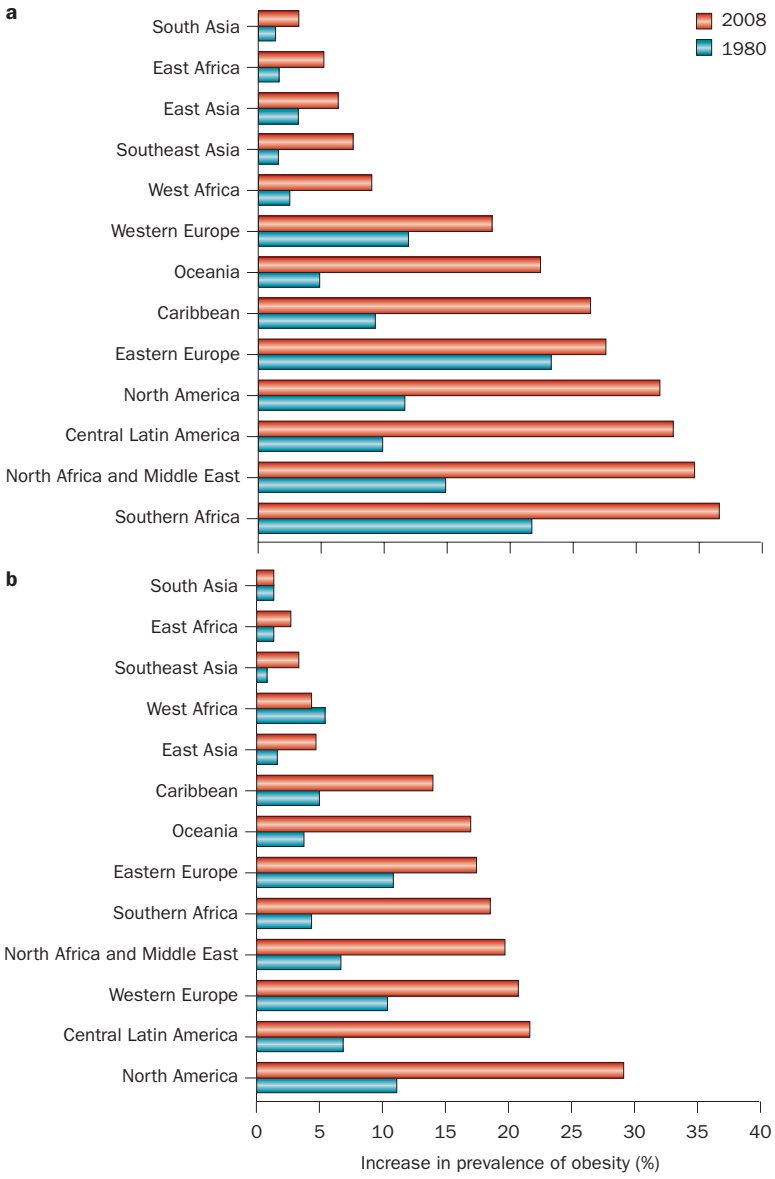


Figure 1 | Global trends in the prevalence of obesity among women and men in 1980 and 2008 from select regions of the world. Estimates of obesity prevalence in **a** | women and **b** | men are shown. Among women, obesity prevalence increased in all regions. The greatest magnitudes of increase (>20%) were observed in central Latin America, North America and North Africa and the Middle East. The Caribbean, Oceania and Southern Africa had magnitudes of increase ranging from around 14% to 18%. Other regions had increases ranging from >3% in east Asia to close to 7% in Western Europe. For men, obesity increased in all regions except South Asia. The greatest magnitude of increase was observed in North America, with an increase of >18%. In central Latin America, Southern Africa, Oceania, north Africa and the Middle East, Western Europe and the Caribbean prevalence increased by >9–15%. In the remaining regions, prevalence increased by between 1.4% in East Africa and >6% in Eastern Europe. In 2008, the prevalence of obesity in men was highest in North America (29.2%) and in women in Southern Africa (36.5%). Prevalence rates >30% were observed in women in North America, central Latin America, and North Africa and the Middle East. All regions are considered low-income and middle-income countries except North America, Western Europe, and parts of Southeast Asia (Brunei Darussalam, Japan, Republic of Korea, Singapore). Oceania does not include Australia and New Zealand. Adapted from Finucane, M. M. *et al.* 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**, 557–567 (2011).

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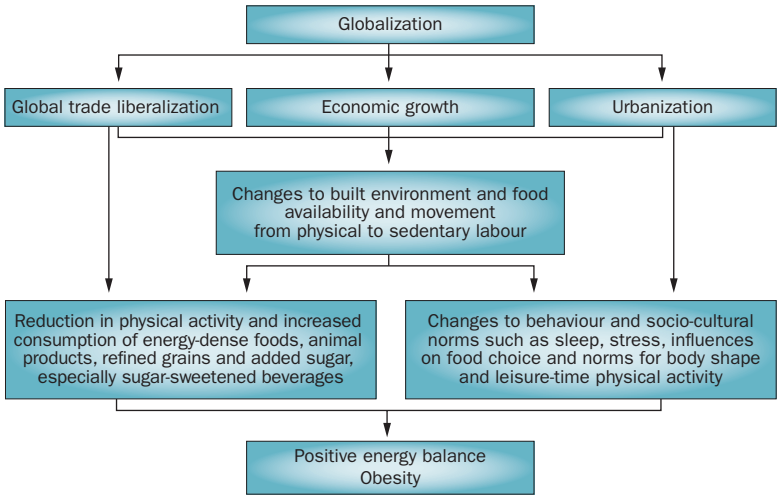


Figure 2 | Schematic representation of the relationship between globalization and obesity. The macro-level factors, global trade liberalization, economic growth and urbanization, promote the development of obesity through changes to the built environment and food choice. Movement away from physical to sedentary labour occurs, creating obesogenic environments, which affect physical activity levels, diet, behaviours and sociocultural norms. All of these effects combine to create a state of positive energy balance that promotes obesity.

programmes.[29] However, concern over rising rates of obesity has initiated dialogue about how these programmes can be reformulated to help control the obesity epidemic in the USA. The cost of basic food commodities, such as corn and soy, is very low owing to economic strategies for food production including direct and indirect subsidies or tax advantages implemented as part of the farm bill. These crops are highly profitable because they are the raw ingredients of most processed foods and beverages. Corn and soy are also the primary feed for livestock; thus, the prices of beef and poultry are also very low by historic and international standards. By contrast, production of fruits and vegetables, which receives little governmental support, remains expensive.

Cutler *et al.*[30] have suggested that the declining cost of food and movement towards mass preparation has been a major contributor to the obesity epidemic in the USA, which can be extrapolated to other countries experiencing similar changes in food availability and choice. Although these factors are probably contributors, this explanation for the obesity epidemic is insufficient because, if true, people who have more money would tend to be more obese, which is not necessarily the case. Kenneth Rogoff, former Chief Economist for the International Monetary Fund, suggests that the obesity epidemic in the USA is the inevitable consequence of an unregulated capitalistic food system, in which companies compete with each other to entice consumers to eat more of their product.[31] Although the relationship between economics and obesity should be investigated further, economic policies and global trade agreements should be considered when designing preventive strategies.

Income and socioeconomic status

Over the next three to four decades, global *per capita* income is projected to rise at a rate of >2% per year; in LMCs, this increase is expected to be even more rapid.[7] The prevalence of obesity correlates positively with the initial stages of economic growth and development, as populations of rapidly developing LMCs 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.[32] This association declined as countries achieved upper-middle-income and high-income status,[32] primarily as a result of improved access to health services and education, as well as behavioural changes.[9] As average income increases, habits associated with obesity, such as television viewing, purchasing convenience foods at supermarkets and consuming highly processed, fast food are adopted. However, access to heath care, education, healthy food and recreational activities that permit weight maintenance remain limited. Another study, in which data from 54 LMCs were analyzed, showed that for a US$1,000 increase in *per capita* GDP, BMI increased by 0.4 kg/m^2.[33] Only in countries with a GDP >US$5,500 (Azerbaijan, Brazil, Columbia, Egypt, Gabon, Namibia, Peru and Turkey) did the quartile of the population with the highest income have a lower prevalence of overweight than the quartile with the lowest income.[33]

Within countries, obesity is related to socioeconomic status. In many LMCs, body weight is positively associated with socioeconomic status, which contrasts with general patterns observed in the USA and other high-income countries, where weight status tends to be inversely associated with socioeconomic status. However, in some populations within high-income countries, positive associations between socioeconomic status and body weight have been shown. For example, in the USA, a higher prevalence of obesity exists in non-Hispanic black or Mexican–American men with a high income (income:poverty ratio ≥350%) than in those with a low income (income:poverty ratio <130%).[34] A lower prevalence of obesity exists in women in the USA with a high income than in women with a low income; however, most women in the USA with obesity do not have a low income. Specifically, 9.5 million women with a low income have obesity, whereas 14.2 million women with a high income have obesity.[34]

The association between socioeconomic status and body weight is thought to be dependent on the level of economic development in the country. In a review of nationally representative surveys from women in 37 LMCs, the burden of obesity was shown to shift towards low socioeconomic groups as *per capita* Gross National Product (GNP) of a country increased to around US$2,500.[35] Examples of countries with a *per capita* GNP >US$2,500 include Mexico, Brazil, Turkey and South Africa.[20]

Urbanization

The proportion of the world's population living in urban areas has increased markedly, from 13% in 1900 to almost 50% in 2005.[7] This trend is expected to continue,

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primarily in countries where the vast majority of the population is currently rural. Urban sprawl (outward spreading of a city and its suburbs), which has been associated with obesity in the USA,[36] is already occurring in some LMCs as urban areas start expanding. Globally, 93% of urban growth is estimated to occur in LMCs, with 80% of growth occurring in Asia and Africa.[37] In China, for example, more than 1 billion people are projected to be living in urban centres by 2050, which is nearly twice the size of the current urban population of the country.[38] 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 and the range of food options available, as well as through lifestyle alterations related to technological advancement and mechanization. Collectively, these changes have a direct effect on diet quality and energy expenditure. These trends of positive energy balance are expected to continue as urbanization continues.

Widespread urbanization has also contributed to a decrease in availability of farmland, displacing farmers to urban areas to seek employment.[39] Both of these changes have an effect on the range of food available by reducing the supply of fresh local produce and reducing the energy expenditure of workers. At the same time, urbanization facilitates greater access to health care and education, which have beneficial effects on obesity.[9] However, many LMCs undergo urbanization at such a rapid pace that the development of essential infrastructure is not yet in place. The shift towards a more mechanized and technologically driven way of life has led to increasingly sedentary lifestyles and low energy expenditure. The combination of increased caloric intake and reduced energy expenditure can have a considerable effect on the development of obesity. Low energy expenditure decreases energy requirements, allowing excess calories to accumulate quickly.[40]

Physical activity

Densely populated areas with little outdoor recreational space limit the opportunities for walking and leisure-time physical activity. Modest benefits of physical activity, including walking and cycling, on weight have been shown, with more-appreciable effects being seen when lifestyle changes occur in combination with dietary intervention.[36] Current physical activity guidelines for prevention of chronic diseases recommend ≥30 min of moderate physical activity on most days of the week.[41–43] Data from the USA show that levels of physical activity for leisure have been fairly stable or have increased over the past 50 years.[44] However, levels of physical activities related to work, transportation and household chores have declined dramatically, and sedentary behaviours such as television viewing and screen time (internet and computer use) have increased substantially, leading to an overall reduction in total physical activity.[44]

In many LMCs, a pronounced movement has occurred away from jobs with high-energy expenditure such as farming, mining, and forestry, towards employment in the more-sedentary sectors of manufacturing, services, and office-based work. This trend is typical of countries experiencing economic transition and urbanization, and these processes will determine the timeframe over which such movements take place.[20] In addition, the use of computer technology, factories and mechanization has 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% between 1989 and 2004.[40] Household chores have also become increasingly mechanized with the emergence of automatic domestic devices, such as washing machines and vacuum cleaners.[2]

Leisure time activities have also become more sedentary with a shift from outdoor play to indoor entertainment such as television viewing, internet use and computer gaming.[2] In China, results of a study published in 2005 showed that <25% of adults reported participation in ≥30 min per day of moderate physical activity,[45] and television ownership increased from 38 sets per 1,000 persons in 1985, to 155 per 1,000 in 1990 and 270 per 1,000 in 1997.[39] At that point, close to 90% of Chinese households owned a television.[46] Similarly, in Korea, time spent viewing television increased by 72% between 1983 and 2001.[47] A link between time spent watching television and weight gain in both children and adults has been shown, and evidence exists that reducing sedentary behaviour has beneficial affects on weight independent of exercise.[45]

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 been estimated to decrease from 37% and 26%, respectively, in cities with 100,000–250,000 inhabitants to 28% and 9% in cities with >5 million inhabitants.[48] For example, in China, construction of a >140,000 km Asian Highway Network is underway, whereas the size of bicycle lanes in Shanghai and Beijing has been restricted.[49] Another major shift affecting energy expenditure in LMCs is the displacement of human-propelled modes of transportation, such as bicycles, in favour of motorized transportation, including cars and mopeds. In India, the annual rate of motor vehicle ownership increased by 11% over the past decade and, in 1997, the number of privately owned motor vehicles was 37.2 million.[50] According to media reports, in China, new car sales increase by an estimated 30% per year.[49]

Behavioural change and sociocultural norms

Certain behavioural changes brought about by urban living could also contribute to the development of obesity in LMCs. Urbanization is associated with a decrease in sleep duration, as noise pollution, street and domestic lighting, access to television and the internet, shift working and night-time social activities are more common in urban areas than in rural areas. Short sleep duration has been associated with weight gain in both children and adults in developed countries, such as the USA.[51,52] Similar evidence is starting to emerge

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from various LMCs including Senegal, Tunisia, Brazil and Taiwan.[36,53–56] In rapidly urbanizing LMCs, stress, which is a risk factor for obesity,[36] might become more prevalent owing to increased occupational demands or reduced societal support in urban centres in comparison with traditional village settings.

Diet

Changes to the range of food options available have been as profound as those in physical activity. As many countries experience rapid economic growth and changes to food choice and availability brought about by urbanization, concomitant shifts in dietary structure or nutritional transitions occur that promote overnutrition and positive energy balance. These transitions are also fuelled by reductions in prices of low-quality foods that are high in energy and increases in GDP, which are indicative of increases in family income and enhanced purchasing power.[8,20] In the past three to four decades, a large number of fast food outlets have opened worldwide.[57] For example, the global number of McDonald's® outlets grew from 951 in 1987 to 7,135 in 2002.[2] Fast food has been linked to obesity and cardiometabolic disease for numerous reasons, including high calorie content, large portion sizes, high amounts of processed meat, highly refined carbohydrates, sugary beverages, unhealthy fats, and unhealthy levels of salt and sugar.[58] Epidemiological studies have shown positive associations between the consumption of fast food and weight gain and adverse metabolic outcomes.[59–61] A prospective cohort study of more than 43,000 Chinese adults enrolled between 1993 and 1998 living in Singapore found that those who consumed Western-style fast food more than twice a week had a 27% increased risk of developing T2DM and a 56% increased risk of mortality due to coronary heart disease, compared with those who reported little or no intake.[62]

Another important shift has been the increase in multinational, regional and large local supermarkets, which are rapidly displacing fresh food markets and farm shops.[8] In just one decade, the number of supermarkets in Latin America increased by an amount equivalent to that which occurred over half a century in the USA.[63] This same process is also occurring at varying rates and at different stages in Asia, Eastern Europe and Africa.[64] The effect of supermarket use on diet quality and obesity can be substantial, as they are a source of highly processed foods, high-energy snack foods, sweets and sugary beverages. In countries where these options are becoming newly available and in countries where they already exist, educational campaigns and policy initiatives are needed to help consumers make healthy choices. Large-scale food and beverage marketing campaigns such as those in which billboards are used could also adversely affect obesity through altering purchasing behaviours towards unhealthy choices.[6]

Although enormous variability exists in dietary patterns between and within countries, and limited data are available to document dietary shifts, some broad themes are apparent, such as the global increase in the consumption of fats and animal products.[8,20] For example, the global consumption of foods from animal sources more than tripled in rural areas and almost quadrupled in urban areas between 1989 and 2000.[40] In China, between 1992 and 2002, the proportion of energy obtained from fat and from animal sources increased from 22.0% to 29.8% and from 9.3% to 13.7%, respectively.[39] Over a similar timeframe, consumption of cereals and vegetables decreased, whereas the *per capita* intake of vegetable oils increased dramatically from 14.8 g per day in 1989 to 35.1 g per day in 2004, adding an extra 183 kilocalories to the diet.[39,40] If these trends continue, by 2020 people in developing countries will consume an estimated 107 million metric tons more meat than they did in the years 1996–1998, surpassing increases in developed countries of 19 million metric tons.[65]

In epidemiological studies, intake of red and processed meat has been associated with weight gain,[66] T2DM,[67] heart disease,[68] some cancers[69] and mortality.[70] In terms of fat consumption, the increased intake *per se* is not the problem, but rather the type or quality of fat consumed. Foods high in monounsaturated and polyunsaturated fats have been associated with a number of health benefits, but the opposite is true for saturated and *trans* fats.[71–73] Data on *trans* fat intake are sparse in LMCs, but labelling and regulation of *trans* fats are not yet required in many countries; therefore, intake could be increasing, particularly owing to consumption of imported foods that contain partially hydrogenated oils that prolong shelf life.[74] Dalda, a type of vegetable ghee, or clarified butter, is a major source of edible oil in India and has a *trans* fat level of ~50%.[75] *Trans* fats have been associated with adverse cardiometabolic risk profiles and could have a role in the development of insulin resistance.[76]

Another major characteristic of nutritional transition is a shift from intake of whole grains to highly refined carbohydrates, such as polished white rice and refined wheat flour. Milling and processing whole grains to produce refined grains, consisting primarily of starch, removes the fibre and numerous micronutrients and phytochemicals. Refined carbohydrates have high glycaemic index (GI) and glycaemic load (GL) values and their consumption produces rapid blood glucose excursions. Temporal data from the USA show an association between intake of refined carbohydrates and risk of obesity and T2DM.[77] In a pooled study of three large prospective cohorts, among the greatest contributors to long-term weight gain were potato chips and potatoes, which have similar GI and GL to refined grains, sweets and sugary beverages.[66] By contrast, whole grains, nuts, fruit, vegetables and yogurt were associated with less weight gain.

In an Indian population, nearly half of an average individual's daily energy intake was estimated to come from refined grains, with polished white rice constituting >75% of refined grain intake.[78] In China, white rice accounts for >30% of an average individual's daily caloric intake.[79] In a meta-analysis of prospective cohort studies in Asian and Western populations, for each increment of one serving per day of white rice, the risk of

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T2DM increased by 11% (RR 1.11, 95% CI 1.08–1.14).[80] Associations were stronger among Asian populations than in Western populations owing to larger quantities of white rice consumed by Asian populations.[80] The adverse effects of high GI and GL diets tend to be more evident in individuals with overweight or obesity,[81,82] who are generally more insulin-resistant than individuals who are lean. This association is of great concern as the global obesity epidemic continues to worsen, because more people will be susceptible to the glycaemic effects of high GI and GL diets. 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 high GI or GL diets were probably offset by high levels of physical activity.

In the past three to four decades, consumption of added sugar in the form of sugar-sweetened beverages has increased dramatically across the globe. Sugar-sweetened beverages promote weight gain as they do not induce high levels of satiety. When calories are consumed in liquid form they are not compensated for by a reduction in caloric intake at subsequent meals, resulting in increased energy intake and positive energy balance. Sugar-sweetened beverages contribute to an increased risk of T2DM by inducing not only weight gain but also the glycaemic effects of consuming large amounts of rapidly absorbable sugars and the metabolic effects of fructose.[83] A number of epidemiologic studies have shown strong associations between sugar-sweetened beverage intake and weight gain or obesity,[66,84] T2DM[85] and coronary heart disease.[86,87]

In the USA, the *per capita* daily consumption of calories from sugar-sweetened beverages doubled from 64.4 kilocalories to 141.7 kilocalories between 1977 and 2006.[88] However, intake of added sugars in the USA decreased from 18.1% of total energy to 14.6% between 2000 and 2008.[89] This decrease resulted primarily from reductions in sugar-sweetened beverage intake, possibly reflecting the success of public health efforts to limit this intake. However, soft drinks continue to be the largest source of added sugars in the diet of the population of the USA.[89] According to nationwide surveys, adolescents and young adults in the USA currently exceed American Heart Association recommendations for added sugar intake of ≤100–150 kilocalories per day, consuming >200 kilocalories per day on average.[88,90]

Data on sugar-sweetened beverage intake in LMCs are scarce. However, in a cross-sectional study of 4,629 adults in China, 20% of men consumed two to three sugar-sweetened beverages per day.[91] In Mexico, ~10% of total energy intake in all age groups comes from sugar-sweetened beverages.[83] In both Brazil and China, daily *per capita* volume sales of sugar-sweetened beverages increased 269% and 147% for Coca-Cola® and PepsiCo®, respectively, between 2000 and 2010.[92] In India, the average annual growth rate for sales of all sugar-sweetened drinks was 12.6% between 1997 and 2007.[93]

In a randomized clinical trial, replacement of caloric beverages with noncaloric beverages for 6 months resulted in average weight losses of 2.0–2.5%.[94] Taken together, these data along with the data presented above show that restricting consumption of sugar-sweetened beverages can be an effective strategy for reducing calorie intake, obesity and related comorbidities, including T2DM, in the USA and globally.

Box 1 | Summary of levels of policy strategies for obesity prevention

Obesity as a global priority
High-level policy changes from the international community will help governments create national guidelines and health outcome surveillance systems, and increase global awareness.

Obesity as a national priority
National guidelines and initiatives can improve diet and physical activity at the population level. Low-income and middle-income countries must create health systems that can combat obesity, chronic diseases, infectious diseases and undernutrition.

Nutritional and agricultural policies
Regulating food consumption and production should be aligned with evidence-based national dietary goals. Labelling, banning, taxation, subsidies and price adjustments can incentivize healthy choices and deter unhealthy choices.

Nutritional labelling
Nutritional labelling of foods can guide consumers in making healthy and informed dietary choices. Menu labelling in restaurants can positively influence food choices and intake. Awareness campaigns should precede or accompany labelling initiatives.

Schools
Nutritional education and improved standards of school meal programmes, including healthy beverage and vending-machine policies, should be part of the global childhood obesity prevention agenda.

Food marketing to children
Regulation of advertising targeted towards children should be adopted globally to reduce the adverse effects of the marketing of unhealthy foods and beverages to children.

Transport and urban planning
Governments should promote active living and facilitate public transportation and bicycle use. Urban planning should encourage development of safe, pedestrian-friendly communities with green spaces.

Physical activity
Physical activity guidelines and educational campaigns should be established and publicized.

Media campaigns
Mass media is essential for delivering public health messages about healthy diets and lifestyles. Large-scale education campaigns should accompany policy initiatives to increase public awareness and support.

Health-care initiatives
Support for patients should be provided to improve dietary habits and physical activity levels. Medical associations have central roles in advocacy and can influence policy.

Individual behaviours
Improving diet and physical activity ultimately rests with individuals. Caregivers should act as role models to instil health-promoting behaviours in youth.

Policies on obesity

Given the scope and complexity of the global obesity epidemic, prevention strategies and policies across multiple levels are needed to have a measurable effect in terms of reversing this trend. Such strategies should include coordinated efforts from the international community, governments, the food industry, health-care providers, schools, urban planners, agriculture and food production and services sectors, the media, communities, and individuals (Box 1).

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Obesity prevention as a global priority

A major milestone in the global response to prevention of chronic diseases was achieved in September 2011, when the United Nations (UN) General Assembly convened a high-level summit on noncommunicable diseases worldwide.[95] This meeting facilitated dialogue between heads of state and governments who identified key targets for strengthening and shaping primary prevention to reduce the prevalence of major risk factors for noncommunicable diseases, such as tobacco use, alcohol abuse, physical inactivity and an unhealthy diet.

In the political declaration of the meeting, two urgent tasks were identified.[96] The first was to ensure widespread distribution of the declaration across all levels of government, the media, academia and the public. The second was to successfully deliver the four short-term commitments of the declaration, which include development of a comprehensive global monitoring framework, development of partnerships to carry forward multisectoral actions, strengthening of national policies and preparation of a report as a basis for a comprehensive review by 2014.[96] The declaration stresses the importance of research and development and international cooperation (including providing access to medicines) to enable these goals to be met.[96] By targeting physical inactivity and an unhealthy diet, this declaration aims to have a direct effect in reducing the risk of obesity, a major risk factor for noncommunicable diseases. The global monitoring framework, in particular, could be a useful tool for tracking obesity trends to help identify countries where obesity policies are needed the most.

The WHO Global Strategy for the Prevention and Control of Noncommunicable Diseases,[97] along with the Moscow Declaration on Healthy Lifestyles and Noncommunicable Disease Control,[98] provide an additional global vision and action plan for the prevention and control of noncommunicable diseases. The WHO has also developed dietary recommendations for health, calling for an elimination of *trans* fat use, a shift from saturated to unsaturated fat usage, a reduction in salt and added sugar intake, and an increase in intake of fruits, vegetables, legumes, whole grains and nuts.[99] In addition, the WHO have set out age-specific recommendations for physical activity to help countries implement national guidelines and create policies and interventions that promote active and safe commuting, and encourage creation of space for recreational activity.[43] At a 2006 ministerial conference on counteracting obesity, which was organized by WHO Europe, member states adopted the European Charter on Counteracting Obesity.[100] Policies recommended as a result of this conference will also become part of the new European health policy —Health 2020—that is currently being developed by WHO Europe.[100]

Marked health inequalities exist between regions, between countries and within countries owing to an unequal distribution of power, money and resources that determine the conditions of everyday life. A global movement towards changing these social determinants of health has been gaining momentum and could have an important effect on obesity and chronic disease prevention. The WHO Commission on Social Determinants of Health brought together a global evidence base, outlining measures that can be taken to reduce health inequalities between and within countries, demonstrating that economic and social policy, if done well, can improve population health equality.[101]

In October 2011, the WHO convened a global conference to build support for the implementation of action on social determinants of health, which culminated with the adoption of the Rio Political Declaration.[102] This declaration expresses global political commitment for the implementation of an approach to reduce health inequities. The three overarching recommendations are: to improve daily living conditions; to tackle the inequitable distribution of power, money and resources; and to measure and understand the problem and assess the effect of action taken. In response to the increasing incidence of childhood obesity, the WHO has also developed population-based prevention strategies specifically for childhood obesity.[103] These strategies include comprehensive and coordinated interventions, which support and facilitate physical activity and healthy diets. Implementation of such interventions is recommended across the whole population in a variety of settings through multiple strategies. Surveillance, monitoring and evaluation are recognized as critical for supporting effective action.

Obesity prevention as a national priority

At the time of writing, a number of obesity prevention programmes have been implemented in high-income countries. For example, in the USA, the Department of Health and Human Services launched the Healthy People campaign, which is a set of goals and objectives with 10-year targets designed to guide national health promotion and disease prevention efforts to improve the health of the population. The US Department of Agriculture updates dietary guidelines for the US population every 5 years and, in 2008, the government issued national age-specific physical activity guidelines.[42] The Let's Move campaign is a comprehensive initiative dedicated to reducing childhood obesity across the nation.[104] As part of this campaign, a taskforce was created to review programmes and policies related to childhood nutrition and physical activity, and develop a national action plan with fixed benchmarks.

In the UK, a report from the Foresight programme (Government Office for Science) was released in 2007, in which the evidence base to identify sustainable solutions to the obesity epidemic in the UK over the next 40 years was reviewed.[105] The report, which has formed the basis of the UK government's strategy on obesity,[106] demonstrated that obesity is a complex problem requiring multidimensional solutions involving every branch of society, and the obesity problem was likened to the climate change challenge in having underlying social and economic factors.[107]

The incidence of obesity and related chronic diseases is increasing more rapidly in many LMCs than in high-income countries. Therefore, implementation

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of effective national prevention strategies in LMCs is urgently required to catch up with decades of progress in high-income countries. Although many LMCs already have national policies or strategies for the prevention of obesity and chronic diseases, a lack of resources for implementation and evaluation of programmes limits their delivery.[96] For example, in 2005 the Ministry of Health in India spearheaded a national T2DM prevention campaign. However, awareness of the programme has not been evaluated on a national level and remains low according to estimates made on the basis of a diabetes mellitus awareness study conducted in Chennai, in southern India.[50] In China, national dietary guidelines have been developed and these were published in 2011; however, dissemination and promotion have been limited.[74]

In many LMCs, problems of underweight, stunted growth and micronutrient deficiencies co-exist with problems of increasing rates of obesity. This complexity represents a major challenge for those designing and implementing food programmes and policies, as food security must be addressed without contributing to the obesity burden and *vice versa*. In light of increasing rates of child obesity, for example, a government food assistance programme in Mexico has reduced the fat content of milk used in welfare and feeding programmes received by approximately 20 million people.[109,108] The outcome of this programme is yet to be evaluated. LMCs must place emphasis on creating health systems that can balance obesity and their associated chronic diseases with infectious diseases and undernutrition. Obesity prevention at the national level in LMCs requires coordination from multiple sectors to implement large-scale campaigns and resource allocation, which might best be accomplished by creating multisectoral task groups within and across government ministries.

Nutritional and agricultural policies

Nutritional and agricultural policies can be powerful instruments for preventing obesity if they are aligned with evidence-based national dietary goals. Some countries, including the USA, Canada and Brazil, require that industrially produced *trans* fats be listed on nutrition labels.[110–112] Legislation for removal of *trans* fats from the food supply has been enacted in Canada, Denmark, Austria, Switzerland and some cities and states of the USA.[110–113] In addition, Brazil, Argentina, Chile and South Africa have also taken steps to reduce or eliminate *trans* fats from food.[110–113] Other countries, including LMCs, can adopt similar measures to replace use of partially hydrogenated oils with oils that include omega-3 fatty acids. These initiatives should be supported by government regulation, which could include incentives for the production and use of oils that are healthier, but this approach would require the agricultural and food industry sectors to work together.

Combining incentives and deterrents can be an effective strategy to encourage production and consumption of nutritionally beneficial foods. Taxation of select foods and beverages, particularly sugar-sweetened beverages, is an approach being considered by some governments as a means to improve public health and generate revenue. Denmark, Hungary and France increased taxes on sugar-sweetened beverages in 2010, 2011 and 2012, respectively. Many other countries, including the USA,[114] UK[115] and Brazil,[116] have initiated discussions about implementing such taxes. Whether these programmes will have the desired effect is yet to be determined.

An analysis of US sales taxes for sugar-sweetened beverages, and individual-level data on BMI in children, demonstrated that existing taxes on these drinks do not substantially affect overall levels of product consumption or rates of obesity.[117] However, most of the taxes were probably too low to result in any attributable change in consumption, given the many other determinants of intake, such as habit, social desirability and preference. Nevertheless, the investigators of this study did find a significant inverse association between increases in differential sugar-sweetened beverage tax (a tax on these beverages that is greater than that on other food items) and BMI. The association was greater in subgroups of children at a higher risk of obesity who were already overweight, from low income families, African American or had higher BMIs than in subgroups of children who were not at risk of obesity.[117] Denmark has imposed a tax on foods with a saturated fat content above 2.3%, and is the first country in the world to have imposed a tax on saturated fat. Whether this policy will improve the health of the Danish population is not yet known.

In 2012, the Organisation for Economic Co-operation and Development released an updated report on obesity and the economics of prevention, in which the authors considered whether implementation of taxes on unhealthy foods and beverages is an answer to stemming the obesity epidemic.[118] In their opinion, if a tax is well designed and covers all possible substitute foods, consumers will probably decrease their consumption of unhealthy foods and, at the same time, spend more on the taxed foods than they used to. They also believe that revenues from taxes would offer invaluable opportunities to attenuate any regressive effects of an unhealthy diet or otherwise increase the public health benefits. For example, subsidies on healthy foods or health education campaigns could be funded by revenues from taxes on unhealthy foods.

Removal of subsidies on foods from animal sources, oils and sugar would increase the cost of these products globally, leading to reduced consumption. In China, an increase in the price of pork, eggs and oil was associated with a reduction in the intake of these products, illustrating that food prices can influence purchasing behaviour and diet quality, particularly among the low-income population.[119] Whether adjusting food pricing in favour of health-promoting food and drink is possible remains unclear, but represents an important global long-term goal. However, the influence of the food industry on government policy is particularly strong at the national level and efforts to address the obesity epidemic, such as taxation on sugar-sweetened beverages, could be blocked. Thus, progress could be made

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more readily at the city or state level, as has been shown already with regards to bans on smoking and *trans* fat use in the USA.

The design and implementation of food pricing policies, such as agricultural subsidies, should emphasize the need to increase accessibility to and affordability of fruits, vegetables, legumes, nuts and whole grains. In 2000, India produced 26.6 million tons of fruit and 96.5 million tons of vegetables.[50] However, inaccessibility and high costs prohibited consumption of these foods in all but affluent, urban populations. In parts of the USA, access to fruit and vegetables has been shown to differ by ethnicity and socioeconomic status.[120] The US farm bill should be amended to increase the availability of healthy food, including fruits and vegetables. Such an amendment is one way in which diet quality could be effectively improved at the population level.[29]

The Supplemental Nutrition Assistance Program, which provides US$75 billion per year in subsidies to 47 million US citizens, can be used to purchase sugar-sweetened beverages and other foods and drinks that adversely affect health.[121] This programme could be amended by applying the standards that are used for other US food assistance programmes, such as the Women, Children and Infant programme. This programme restricts purchases of unhealthy food and drink and, if the same standards were applied to the Supplemental Nutrition Assistance Program, it would have a transformative effect on food purchases in the USA, as a large proportion of the population is enrolled in this programme. In China, subsidies on fruits, vegetables and soybeans have been an effective approach to increase production and consumption of these products.[122]

Voluntary actions and regulations made by industry could be useful strategies for improving diet quality both countrywide and worldwide. An initiative to remove 1.5 trillion calories from the total supply of processed foods in the USA by 2015 is currently underway by 17 leading food companies.[109,123] In the UK, some of the biggest supermarkets, food manufacturers, caterers and food outlets are also joining forces to help cut 5 billion calories from the nation's daily diet.[124] Translating similar initiatives to other countries, particularly LMCs, represents another important global long-term goal.

Policy implementation

Lifestyle interventions

Some of the strongest evidence for a beneficial role of diet and lifestyle modification on prevention of obesity and chronic diseases, particularly T2DM and cardiovascular disease, comes from large intervention studies in high-risk individuals. In such studies, strategies employed involve education and lifestyle counselling to motivate behavioural change. Large-scale intervention programmes in China,[125] Finland,[126] the USA[127] and India[128] have demonstrated that body weight control and moderate changes in diet and physical activity are better than pharmaceutical intervention for preventing T2DM in high-risk individuals from diverse populations. These initiatives also reduced the prevalence of T2DM long after the end of active intervention, illustrating sustained behavioural changes.[129]

Studies in which community-based strategies were employed have also shown beneficial effects on chronic disease prevention. For example, the China Seven Cities Study showed that community-based health education campaigns, in combination with control of hypertension, coronary heart disease and T2DM, significantly reduced stroke incidence and mortality.[130] The North Karelia project began in Finland in 1972 and showed that an integrated community-based intervention on diet and lifestyle can reduce coronary heart disease risk and mortality by more than 80%.[131] The general aim of this study was to raise awareness about the severity of the disease and transform the social and physical environment of the community by working closely with health services, schools, nongovernmental organizations, supermarkets, the food industry, community leaders and the local media. Strategies employed included educational campaigns, risk factor surveillance, reducing and modifying the fat and salt content of foods, and implementing incentives to increase farming of fruits and vegetables.[131] After the initial 5 years (1972–1976)of the project, strategies were scaled up to the national level and continued over the next decade, including creation of expert guidelines, banning tobacco advertising and a national risk factor monitoring system.[132,133]

A community-based intervention progamme initiated in France, EPODE (Ensemble, prévenons l'obésité des enfants [Together, let's prevent obesity in children]), is currently being implemented in more than 500 cities and towns in Europe and in South Australia.[133] The intervention involves community-wide voluntary activities, such as removing vending machines from schools, restricting unhealthy food and beverage promotion to children, education campaigns, recommendations on nutrition content of foods and labelling, and promotion of physical activity organized by families, schools, health departments, grocers, the media, physicians and other health professionals. Studies conducted within the EPODE programme have shown that childhood obesity is reduced in towns that implement prevention strategies, compared with matched control towns and national averages.[134,135]

A 3-year environmental change intervention in the USA has been shown to reduce obesity in culturally diverse, high-risk, school-aged children.[136] On the basis of these results, a community wellness policy for nutrition, physical activity and nutritional education was established by the Somerville, Massachusetts, USA school department. School-based interventions to improve diet and physical activity have been shown to have beneficial effects on body weight in children.[137] The 2-year nutrition and physical activity intervention in Massachusetts resulted in a reduction in obesity among children aged 11–13 years. The programme has been translated into an interdisciplinary teaching curriculum that is available for use in schools and has been implemented in various schools in Massachusetts.[137] In New York City, the prevalence of obesity in school children decreased by 5.5% from 2006 to 2007 and 2010 to 2011

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following implementation of public-health interventions including a school fitness programme.[138]

Nutritional labelling

Regulations for labelling calorie and nutrient content of foods—particularly saturated fat, *trans* fat and sodium levels—can guide consumers to make healthy and informed dietary choices. Although country-specific variations exist, a number of countries including the USA, Canada, New Zealand, Australia, India, Mexico and the countries of the European Union require nutritional facts or information labels on the side, bottom or back of most packaged foods that list the amounts of calories, saturated and *trans* fats, sodium, cholesterol, macronutrients and various micronutrients per serving. Front-of-package labelling conveys essential nutritional information in a prominent manner and usually consists of a short, clear label or simple symbols. An example of this type of labelling is the traffic light system of food packaging used in the UK, in which high, medium and low levels of fat, saturated fat, sugar and salt are indicated by the traffic light colours red, amber and green.[139]

Nutritional labelling is emerging as a major global initiative and a number of LMCs, including India, China, Brazil, Mexico, South Africa and Chile, are also considering developing systems beyond nutrition facts panels that identify nutritionally beneficial foods and beverages.[109] 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 make healthy choices. These initiatives hold promise in the context of the increasing availability of processed and packaged foods that is accompanying increasing rates of urbanization in LMCs. Menu labelling in fast-food outlets and restaurants is another strategy being considered in parts of the USA. In New York City, calorie labelling on chain restaurant menus was shown to have beneficial effects on food choices and caloric intake.[140] Educational campaigns must precede or accompany both food-package and menu labelling to raise awareness about these initiatives and to provide context, so that people understand why they are important and know both to look for the labels and how to interpret them.

School-based initiatives

School meal programmes and policies related to vending machines are powerful tools to address childhood obesity and should be part of the global prevention agenda along with nutritional education about healthy diet and education about active lifestyles. These strategies should be reinforced through provision of educational pamphlets to parents. School meal programmes are designed to provide low-cost or free meals to ensure nutritional adequacy among school children and can be used to encourage healthy eating habits for obesity prevention whilst preventing undernutrition. Although many children depend on school meals, others might bring food in from home or elsewhere. In such cases, a healthy school-food environment could serve as a model for healthy eating overall and, along with nutritional education for students and parents, could encourage healthy dietary choices. For example, the US Institute of Medicine has released recommendations to improve standards of national school lunch and breakfast programmes by increasing the amount and variety of fruits, vegetables and whole grains available, setting a minimum and maximum amount of calories for each meal, and focusing on reducing the saturated fat and sodium content of food in schools.[141]

A number of states have also implemented policies banning sales of and access to sugar-sweetened beverages in schools.[148] In Mexico, the Ministry of Health created a set of beverage guidelines that were used to improve school meal and welfare programmes,[142] and banned sales of sugar-sweetened beverages in schools along with foods high in sugar and saturated fat.[109] Policies to limit the availability of sugar-sweetened beverages in schools have also been adopted in various countries in Europe and the rest of the world.[150] 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 fruit, vegetables and milk; access to water; and removal of vending machines containing snacks and beverages of poor nutritional quality.[143]

Food marketing to children

A consequence of globalization in many countries has been an exponential growth in food marketing and advertising, which has created major shifts in food demand because marketing leads people to increase their consumption of advertised products.[109] A growing body of evidence indicates that food marketing can influence the food preferences and consumption habits of children.[144] For this reason, the WHO recommends that governments and industry reduce the amount of advertising and marketing of unhealthy foods to children.[145] However, few countries have taken steps towards reducing such marketing. In France, marketing of foods high in fat, sugar and salt is banned unless they are taxed and labelled with a health warning. Regulation of advertising targeted towards children through television, the internet or other media are important strategies that should be adopted globally to reduce the harmful effects on children of marketing of unhealthy foods such as fast food, sugar-sweetened beverages and nutrient-poor snack foods that are high in energy. At the same time, governments can institute zoning laws, if available, that limit the number of fast-food restaurants in a given area.[58]

Transport and urban planning

Evidence from a number of countries supports the crucial relationship between physically active modes of transport, obesity and T2DM.[146] Governments should promote and facilitate use of public transportation and bicycles by providing incentives including discounted transportation fares, bicycling sharing programmes, cycling safety classes and secure bicycle parking. Reduced

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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. Creation of a central policy for urban transportation could be a first step for some countries. Governments should also mandate construction of sidewalks and safe bicycle lanes for commuting, and construction of buildings with features such as accessible staircases that promote fitness. 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.

Physical activity

To complement efforts related to transport and urban planning, national physical activity guidelines and corresponding health education campaigns should be established to encourage ≥30 min of moderate physical activity on most days of the week. In the USA, physical activity guidelines have been established and widely promoted and have become important tools for health professionals, organizations and policy makers, although their direct effect on obesity has not been formally evaluated.[41,42] Other countries could adopt these guidelines or those published by the WHO.[43] Both the USA and WHO guidelines are similar in that they are evidence-based and set out recommendations by age group (5–17 years, 18–64 years and >65 years); therefore, adopting either set of recommendations would be beneficial. Physical activity classes and education in schools should also be mandated and steps should be taken to reduce sedentary behaviours, such as television viewing.

Media campaigns and social marketing

The mass media, including national-level social marketing and public service campaigns, are essential in order to deliver public-health messages about healthy diet and lifestyle. For example, the Pouring on the Pounds campaign in New York City is a powerful initiative designed to inform the public about the harmful effects of sugar-sweetened beverages and to promote consumption of healthy beverages by using posters on public transportation and a multilingual health bulletin.[147] As with nutrition labelling, education campaigns should accompany policy initiatives, such as taxation of sugar-sweetened beverages, in order to increase public awareness and support. Clear, consistent and culturally specific messages should be delivered through various media, such as television, radio and the internet, as well as in public settings including supermarkets, community spaces, worksites, schools and health-care facilities. These strategies are of particular importance in LMCs with rapidly changing environments and rapidly rising obesity prevalence.

Health-care initiatives

As part of standard medical practice, physicians and other health-care providers should monitor the body weight of patients and provide suitable evidence-based advice about weight management.[148] Patients should be given continued support to improve dietary habits and physical activity for weight loss or maintenance.[148] Medical associations and nongovernmental organizations also have central roles in advocacy and can influence policy on issues related to health and the environment. For example, the American Heart Association released a scientific statement, calling for a reduction in intake of added sugar to improve health, which has become an integral part of the dialogue regarding regulation of sugar-sweetened beverages.[90] Alliances in other countries can adopt similar platforms to advocate policies and programmes to reduce obesity.

Individual-level behaviour

Responsibility for behavioural changes to improve diet and level of physical activity ultimately rests with the individual, although the availability of food items and physical and social environments can influence choices. Individuals can contribute toward creating healthy environments in their homes and communities. Parents and caregivers have particular responsibility and have a great opportunity to instil health-promoting behaviours in children and adolescents by setting examples and acting as role models.[148]

Legal actions

Legal actions have played an important role in the control of asbestos, tobacco and environmental carcinogens.[149] Strong evidence exists that sugar-sweetened beverages are a cause of obesity and T2DM,[83,85] and these products are aggressively promoted to adults and children alike by the food and beverage industry. Similarly, fast-food meals, which can be a major source of saturated and *trans* fats, refined grains, sodium, and sugar are marketed to children with the use of toys and character endorsements. Questions are, therefore, raised about liability related to outcomes such as obesity and comorbidities, particularly as these products do not contain warning labels.[150] This approach of using legal action to control the obesity epidemic deserves further exploration.

Conclusions

Over the past few decades, rapid globalization has had a huge effect on the incidence of obesity and its associated comorbidities in numerous countries, including many LMCs. Although globalization has afforded improvements in quality of life for many individuals, it has also created access to low-cost foods that are low in nutritional value and high in energy, increased the consumption of processed and convenience foods and sugar-sweetened beverages, and increased the proportion of people living in urban environments with infrastructures that promote sedentary lifestyles. Together, these changes are driving the global obesity epidemic. Action is needed from the international community to abate this epidemic, as rapidly rising rates of obesity and associated chronic diseases will result in not only detrimental effects on the health and welfare of populations

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but also prohibitively high health-care costs, particularly in regions that must manage co-existing infectious diseases and undernutrition.

Effective strategies to address obesity on a global scale are likely to require sustained population-wide interventions and policy recommendations to improve diet and increase levels of physical activity. Population-based approaches have the potential to shift the distribution of risk factors of an entire population in a favourable 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. Such efforts require strategies across multiple sectors, from high-level policy changes to individual-level behavioural changes. Continued surveillance of obesity and national health outcomes is also necessary to monitor and evaluate programmes, and maintain awareness among the public and within governments. Positive aspects of globalization, such as increased information flow, improved technology and innovation via international collaboration, should be harnessed to facilitate global efforts for the prevention of obesity.

Review criteria

Literature was chosen by searching PubMed using search terms specific for each section of the Review. Articles published up to 2012 were considered. Terms used included "globalization and obesity", "global burden of obesity", "urbanization and obesity", "socioeconomic status and obesity" and "obesity policy". Literature was also selected from reference lists of papers of interest. Additionally, websites of relevant organizations such as WHO, UN, EPODE and Organisation for Economic Co-operation and Development were scanned for relevant publications. For many topics, articles already known to the authors were used and books belonging to their personal collection were also consulted.

1. Finucane, M. M. *et al.* 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**, 557–567 (2011).
2. Misra, A. & Khurana, L. Obesity and the metabolic syndrome in developing countries. *J. Clin. Endocrinol. Metab.* **93**, S9–S30 (2008).
3. Danaei, G. *et al.* The preventable causes of death in the United States: comparative risk assessment of dietary, lifestyle, and metabolic risk factors. *PLoS Med.* **6**, e1000058 (2009).
4. WHO. Global health risks: mortality and burden of disease attributable to selected major risks. [online], http://www.who.int/healthinfo/global_burden_disease/en/ (2009).
5. Prospective Studies Collaboration *et al.* Body-mass index and cause-specific mortality in 900000 adults: collaborative analyses of 57 prospective studies. *Lancet* **373**, 1083–1096 (2009).
6. Hawkes, C. Uneven dietary development: linking the policies and processes of globalization with the nutrition transition, obesity and diet-related chronic diseases. *Global Health* **2**, 4 (2006).
7. Kearney, J. Food consumption trends and drivers. *Philos. Trans. R. Soc. Lond. B Biol. Sci.* **365**, 2793–2807 (2010).
8. Popkin, B. M. Global nutrition dynamics: the world is shifting rapidly toward a diet linked with noncommunicable diseases. *Am. J. Clin. Nutr.* **84**, 289–298 (2006).
9. Fuster, V. & Kelly, B. B. *Promoting Cardiovascular Health in the Developing World: A Critical Challenge to Achieve Global Health* (eds Valentín Fuster & Bridget B. Kelly) (The National Academies Press, 2010).
10. Huang, E. S, Basu, A., O'Grady, M. &Capretta, J. C. Projecting the future diabetes population size and related costs for the U.S. *Diabetes Care* **32**, 2225–2229 (2009).
11. Finkelstein, E. A, Trogdon, J. G., Cohen, J. W. & Dietz, W. Annual medical spending attributable to obesity: payer- and service-specific estimates. *Health Aff. (Millwood)* **28**, w822–w831 (2009).
12. Kelly, T., Yang, W., Chen, C. S., Reynolds, K. & He, J. Global burden of obesity in 2005 and projections to 2030. *Int. J. Obes. (Lond.)* **32**, 1431–1437 (2008).
13. The World Bank. *How we Classify Countries* [online], http://data.worldbank.org/about/country-classifications/country-and-lending-groups (2012).
14. Caballero, B. A nutrition paradox—underweight and obesity in developing countries. *N. Engl. J. Med.* **352**, 1514–1516 (2005).
15. Beaglehole, R. *et al.* Priority actions for the non-communicable disease crisis. *Lancet* **377**, 1438–1447 (2011).
16. Abegunde, D. O., Mathers, C. D., Adam, T., Ortegon, M. & Strong, K. The burden and costs of chronic diseases in low-income and middle-income countries. *Lancet* **370**, 1929–1938 (2007).
17. Flegal, K. M., Carroll, M. D., Kit, B. K. & Ogden, C. L. Prevalence of obesity and trends in the distribution of body mass index among US adults, 1999–2010. *JAMA* **307**, 491–497 (2012).
18. James, W. P. WHO recognition of the global obesity epidemic. *Int. J. Obes. (Lond.)* **32** (Suppl. 7), S120–S126 (2008).
19. WHO Expert Consultation. Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. *Lancet* **363**, 157–163 (2004).
20. Popkin, B. M. & Gordon-Larsen, P. The nutrition transition: worldwide obesity dynamics and their determinants. *Int. J. Obes. Relat. Metab. Disord.* **28** (Suppl. 3), S2–S9 (2004).
21. Mendez, M. A., Monteiro, C. A. & Popkin, B. M. Overweight exceeds underweight among women in most developing countries. *Am. J. Clin. Nutr.* **81**, 714–721 (2005).
22. WHO. Global strategy on diet, physical activity, and health: childhood overweight and obesity. [online], http://www.who.int/dietphysicalactivity/childhood/en/ (2010).
23. Poskitt, E. M. Countries in transition: underweight to obesity non-stop? *Ann. Trop. Paediatr.* **29**, 1–11 (2009).
24. Singh, A. S., Mulder, C., Twisk, J. W., van Mechelen, W. & Chinapaw, M. J. Tracking of childhood overweight into adulthood: a systematic review of the literature. *Obes. Rev.* **9**, 474–488 (2008).
25. Popkin, B. M., Conde, W., Hou, N. & Monteiro, C. Is there a lag globally in overweight trends for children compared with adults? *Obesity (Silver Spring)* **14**, 1846–1853 (2006).
26. de Onis, M., Blossner, M. & Borghi, E. Global prevalence and trends of overweight and obesity among preschool children. *Am. J. Clin. Nutr.* **92**, 1257–1264 (2010).
27. Harris, J., Kaufman, P., Martinez, S. & Price, C. *The U. S. Food Marketing System, 2002 (agricultural economic report no. 811).* (U. S. Department of Agriculture Economic Research Service, Washington D. C., 2002).
28. Stuckler, D., McKee, M., Ebrahim, S. & Basu, S. Manufacturing epidemics: the role of global producers in increased consumption of unhealthy commodities including processed foods, alcohol, and tobacco. *PLoS Med.* http://www.dx.doi.org/10.1371/journal.pmed.1001235.
29. Weems, S. & Weber, J. A. Farm bill offers opportunity to improve nutrition of all Americans. *J. Am. Diet. Assoc.* **107**, 736–738 (2007).
30. Cutler, D., Glaeser, E. & Shapiro J. Why have Americans become more obese? *J. Econ. Perspect*. **17**, 93–118 (2003).
31. Rogoff, K. Coronary Capitalism. *Project Syndicate* [online], http://www.project-syndicate.org/commentary/coronary-capitalism (2012).
32. Ezzati, M. *et al.* Rethinking the "diseases of affluence" paradigm: global patterns of nutritional risks in relation to economic development. *PLoS Med.* **2**, e133 (2005).
33. Subramanian, S. V., Perkins, J. M., Özaltin, E. & Davey Smith, G. Weight of nations: a socioeconomic analysis of women in low- to middle-income countries. *Am. J. Clin. Nutr.* **93**, 413–421 (2010).
34. Ogden, C. L., Lamb, M. M., Carroll, M. D. & Flegal, K. M. Obesity and socioeconomic status in adults: United States, 2005–2008. *NCHS Data Brief* **50**, 1–8 (2010).
35. Monteiro, C. A., Moura, E. C., Conde, W. L. & Popkin, B. M. Socioeconomic status and obesity in adult populations of developing countries: a review. *Bull. World Health Organ.* **82**, 940–946 (2004).
36. Hu, F. B. *Obesity Epidemiology* (Oxford University Press, New York, 2008).
37. United Nations Population Fund. Urbanization's Second Wave: A Difference of Scale. *State of the World Population 2007* [online], http://web.unfpa.org/swp/2007/english/chapter_1/urbanization.html (2007).
38. United Nations Department of Economic and Social Affairs/Population Division. *World*

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Urbanization Prospects: The 2009 Revision. (United Nations, New York, 2009).
39. Wang, Y., Mi, J., Shan, X. Y., Wang, Q. J. & Ge, K. Y. Is China facing an obesity epidemic and the consequences? The trends in obesity and chronic disease in China. *Int. J. Obes. (Lond.)* **31**, 177–188 (2007).
40. Popkin, B. M. *The World is Fat: The Fads, Trends, Policies, and Products That Are Fattening the Human Race* (Penguin Group, New York, 2009).
41. Pate, R. R. *et al.* Physical activity and public health. A recommendation from the Centers for Disease Control and Prevention and the American College of Sports Medicine. *JAMA* **273**, 402–407 (1995).
42. U. S. Department of Health and Human Services. 2008 Physical Activity guidelines for Americans. *Physical Activity guidelines for Americans* [online], http://www.health.gov/paguidelines/ (2008).
43. WHO. *Global Recommendations on Physical Activity for Health* (WHO, Geneva, 2010).
44. Brownson, R. C., Boehmer, T. K. & Luke, D. A. Declining rates of physical activity in the United States: what are the contributors? *Annu. Rev. Public Health* **26**, 421–443 (2005).
45. Muntner, P. *et al.* Prevalence of physical activity among Chinese adults: results from the International Collaborative Study of Cardiovascular Disease in Asia. *Am. J. Public Health* **95**, 1631–1636 (2005).
46. Du, S., Lu, B., Zhai, F. & Popkin, B. M. A new stage of the nutrition transition in China. *Public Health Nutr.* **5**, 169–174 (2002).
47. Choi, Y. J. *et al.* Rapidly increasing diabetes-related mortality with socio-environmental changes in South Korea during the last two decades. *Diabetes Res. Clin. Pract.* **74**, 295–300 (2006).
48. Singh, A. Review of urban transportation in India. *Journal of Public Transportation* **8**, 79–97 (2005).
49. Kjellström T., Håkansta, C. & Hogstedt, C. Globalisation and public health-overview and a Swedish perspective. *Scand. J. Public Health Suppl.* **70**, 2–68 (2007).
50. Siegel, K., Narayan, K. M. & Kinra, S. Finding a policy solution to India's diabetes epidemic. *Health Aff. (Millwood)* **27**, 1077–1090 (2008).
51. Patel, S. R. & Hu, F. B. Short sleep duration and weight gain: a systematic review. *Obesity (Silver Spring)* **16**, 643–653 (2008).
52. Berkey, C. S., Rockett, H. R. & Colditz, G. A. Weight gain in older adolescent females: the internet, sleep, coffee, and alcohol. *J. Pediatr.* **153**, 635–639 (2008).
53. Bénéfice, E., Garnier, D. & Ndiaye, G. Nutritional status, growth and sleep habits among Senegalese adolescent girls. *Eur. J. Clin. Nutr.* **14**, 762–768 (2004).
54. Ben Slama, F. *et al.* Obesity and life style in a population of male school children aged 6 to 10 years in Ariana (Tunisia) [French]. *Tunis. Med.* **80**, 542–547 (2002).
55. Giugliano, R. & Carneiro, E. C. Factors associated with obesity in school children [Portugese]. *J. Pediatr. (Rio J.)* **80**, 17–22 (2004).
56. Chen, M. Y., Wang, E. K. & Jeng, Y. J. Adequate sleep among adolescents is positively associated with health status and health-related behaviors. *BMC Public Health* **6**, 59 (2006).
57. Yum! Brands. *Defining Global Company that Feeds the World* [online], http://www.yum.com/brands/ (2012).
58. Pan, A., Malik, V. S. & Hu, F. B. Exporting diabetes mellitus to Asia: the impact of Western-style fast food. *Circulation* **126**, 163–165 (2012).
59. Pereira, M. A. *et al.* Fast-food habits, weight gain, and insulin resistance (the CARDIA study): 15-year prospective analysis. *Lancet* **365**, 36–42 (2005).
60. Duffey, K. J., Gordon-Larsen, P., Steffen, L. M., Jacobs, D. R. Jr & Popkin, B. M. Regular consumption from fast food establishments relative to other restaurants is differentially associated with metabolic outcomes in young adults. *J. Nutr.* **139**, 2113–2118 (2009).
61. Rosenheck, R. Fast food consumption and increased caloric intake: a systematic review of a trajectory towards weight gain and obesity risk. *Obes. Rev.* **9**, 535–547 (2008).
62. Odegaard, A. O., Koh, W. P., Yuan, J. M., Gross, M. D. & Pereira, M. A. Western-style fast food intake and cardiometabolic risk in an eastern country. *Circulation* **126**, 182–188 (2012).
63. Reardon, T., Timmer, C., Barrett, C. & Berdegue, J. The rise of super-markets in Africa, Asia and Latin America. *Am. J. Agric. Econ*. **85**, 1140–1146 (2003).
64. Wagner, K. H. & Brath, H. A global view on the development of non communicable diseases. *Prev. Med.* **54**, S38–S41 (2012).
65. Delgado, C. L. Rising consumption of meat and milk in developing countries has created a new food revolution. *J. Nutr.* **133** (Suppl. 2), 3907S–3910S (2003).
66. Mozaffarian, D., Hao, T., Rimm, E. B., Willett, W. C. & Hu, F. B. Changes in diet and lifestyle and long-term weight gain in women and men. *N. Engl. J. Med.* **364**, 2392–2404 (2011).
67. Pan, A. *et al.* Red meat consumption and risk of type 2 diabetes: 3 cohorts of US adults and an updated meta-analysis. *Am. J. Clin. Nutr.* **94**, 1088–1096 (2011).
68. Bernstein, A. M. *et al.* Major dietary protein sources and risk of coronary heart disease in women. *Circulation* **122**, 876–883 (2010).
69. Chan, D. S. *et al.* Red and processed meat and colorectal cancer incidence: meta-analysis of prospective studies. *PLoS ONE* **6**, e20456 (2011).
70. Pan, A. *et al.* Red meat consumption and mortality: results from 2 prospective cohort studies. *Arch. Intern. Med.* **172**, 555–563 (2012).
71. Mozaffarian, D., Micha, R. & Wallace, S. Effects on coronary heart disease of increasing polyunsaturated fat in place of saturated fat: a systematic review and meta-analysis of randomized controlled trials. *PLoS Med*. **7**, e1000252 (2010).
72. Mente, A., de Koning, L., Shannon, H. S. & Anand, S. S. A systematic review of the evidence supporting a causal link between dietary factors and coronary heart disease. *Arch. Intern. Med.* **169**, 659–669 (2009).
73. Appel, L. J. *et al.* Effects of protein, monounsaturated fat, and carbohydrate intake on blood pressure and serum lipids: results of the OmniHeart randomized trial. *JAMA* **294**, 2455–2464 (2005).
74. Hu, F. B., Liu, Y. & Willett, W. C. Preventing chronic diseases by promoting healthy diet and lifestyle: public policy implications for China. *Obes. Rev.* **12**, 552–559 (2011).
75. Popkin, B. M. The nutrition transition and obesity in the developing world. *J. Nutr.* **131**, 871S–873S (2001).
76. Mozaffarian, D., Katan, M. B., Ascherio, A., Stampfer, M. J. & Willett, W. C. *Trans* fatty acids and cardiovascular disease. *N. Engl. J. Med.* **354**, 1601–1613 (2006).
77. Gross, L. S., Li, L., Ford, E. S. & Liu, S. Increased consumption of refined carbohydrates and the epidemic of type 2 diabetes in the United States: an ecologic assessment. *Am. J. Clin. Nutr.* **79**, 774–779 (2004).
78. Radhika, G., Van Dam, R. M., Sudha, V., Ganesan, A. & Mohan, V. Refined grain consumption and the metabolic syndrome in urban Asian Indians (Chennai Urban Rural Epidemiology Study 57). *Metabolism* **58**, 675–681 (2009).
79. Wang, L. *Report of China Nationwide Nutrition and Health Survey 2002, Summary Report* (People's Medical Publishing House, Beijing, 2005).
80. Hu, E. A., Pan, A., Malik, V. & Sun, Q. White rice consumption and risk of type 2 diabetes: meta-analysis and systematic review. *BMJ* http://dx.doi.org/10.1136/bmj.e1454.
81. Sun, Q. *et al.* White rice, brown rice, and risk of type 2 diabetes in US men and women. *Arch. Intern. Med.* **170**, 961–969 (2010).
82. Villegas, R. *et al.* Prospective study of dietary carbohydrates, glycemic index, glycemic load, and incidence of type 2 diabetes mellitus in middle-aged Chinese women. *Arch. Intern. Med.* **167**, 2310–2316 (2007).
83. Malik, V. S., Popkin, B. M., Bray, G. A., Després, J. P. & Hu, F. B. Sugar-sweetened beverages, obesity, type 2 diabetes mellitus, and cardiovascular disease risk. *Circulation* **121**, 1356–1364 (2010).
84. Malik, V. S., Willett, W. C. & Hu, F. B. Sugar-sweetened beverages and BMI in children and adolescents: reanalyses of a meta-analysis. *Am. J. Clin. Nutr.* **89**, 438–489 (2009).
85. Malik, V. S. *et al.* Sugar-sweetened beverages and risk of metabolic syndrome and type 2 diabetes: a meta-analysis. *Diabetes Care* **33**, 2477–2483 (2010).
86. Fung, T. T. *et al.* Sweetened beverage consumption and risk of coronary heart disease in women. *Am. J. Clin. Nutr.* **89**, 1037–1042 (2009).
87. de Koning, L. *et al.* Sweetened beverage consumption, incident coronary heart disease and Biomarkers of Risk in Men. *Circulation* **125**, 1735–1741 (2012).
88. Popkin, B. M. Patterns of beverage use across the lifecycle. *Physiol. Behav.* **100**, 4–9 (2010).
89. Welsh, J. A., Sharma, A. J., Grellinger, L. & Vos, M. B. Consumption of added sugars is decreasing in the United States. *Am. J. Clin. Nutr.* **94**, 726–734 (2011).
90. Johnson, R. K. *et al.* Dietary sugars intake and cardiovascular health: a scientific statement from the American Heart Association. *Circulation* **120**, 1011–1020 (2009).
91. Ko, G. T. *et al.* Risk associations of obesity with sugar-sweetened beverages and lifestyle factors in Chinese: the 'Better Health for Better Hong Kong' health promotion campaign. *Eur. J. Clin. Nutr.* **64**, 1386–1392 (2010).
92. Kleiman, S., Ng, S. W. & Popkin, B. Drinking to our health: can beverage companies cut calories while maintaining profits? *Obes. Rev.* **13**, 258–274 (2012).
93. Taylor, F. C., Satja, A., Khurana, S., Singh, G. & Shah E. Pepsi® and Coca Cola® in Delhi, India: availability, price and sales. *Public Health Nutr.* **14**, 653–660 (2011).
94. Tate, D. F. *et al.* Replacing caloric beverages with water or diet beverages for weight loss in adults: main results of the Choose Healthy Options Consciously Everyday (CHOICE) randomized clinical trial. *Am. J. Clin. Nutr.* **95**, 555–563 (2012).
95. UN General Assembly. Draft political declaration of the high-level meeting on the Prevention and Control of Non-communicable diseases [online],

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http://www.un.org/en/ga/ncdmeeting2011/pdf/NCD_draft_political_declaration.pdf (2011).
96. Beaglehole, R., Bonita, R., Alleyne, G. & Horton, R. NCDs: celebrating success, moving forward. *Lancet* **378**, 1283–1284 (2011).
97. WHO. *2008–2013 Action Plan for the Global Strategy for the Prevention and Control of Noncommunicable Diseases* (WHO, Geneva, 2008).
98. WHO. *First Global Ministerial Conference on Healthy Lifestyles and Noncommunicable Disease Control* (WHO, Geneva 2011).
99. Nishida, C., Uauy, R., Kumanyika, S. & Shetty, P. The joint WHO/FAO expert consultation on diet, nutrition and the prevention of chronic diseases: process, product and policy implications. *Public Health Nutr.* **7**, 245–250 (2004).
100. WHO/Europe. *European Charter on Counteracting Obesity* (WHO Europe, Copenhagen, 2006).
101. Friel, S. & Marmot, M. G. Action on the social determinants of health and health inequities goes global. *Annu. Rev. Public Health* **32**, 225–236 (2011).
102. WHO. World Conference on Social Determinants of Health [online], http://www.who.int/sdhconference/en/ (2012).
103. WHO. *Population-based Prevention Strategies for Childhood Obesity: Report of a WHO Forum and Technical Meeting* (WHO, Geneva, 2009).
104. Let's Move Campaign. Let's Move: America's Move to Raise a Healthier Generation of Kids [online], http://www.letsmove.gov/ (2012).
105. Government Office of Science. *Foresight* [online], http://www.foresight.gov.uk/ (2012).
106. Department of Health. Healthy weight, healthy lives: a cross-government strategy for England [online], http://webarchive.nationalarchives.gov.uk/20100407220245/http://www.dh.gov.uk/prod_consum_dh/groups/dh_digitalassets/documents/digitalasset/dh_084024.pdf (2008).
107. James, W. P. The epidemiology of obesity: the size of the problem. *J. Intern. Med.* **263**, 336–352 (2008).
108. Barquera, S. *et al.* Caloric beverage consumption patterns in Mexican children. *Nutr. J.* **9**, 47 (2010).
109. Popkin, B. M., Adair, L. S. & Ng, S. W. Global nutrition transition and the pandemic of obesity in developing countries. *Nutr. Rev.* **70**, 3–21 (2012).
110. Benincá, C., Zanoelo, E. F., de Lima Luz, L. F. Jr & Spricigo, C. B. *Trans* fatty acids in margarines marketed in Brazil: content, labeling regulations and consumer information. *Eur. J. Lipid Sci. Technol.* **111**, 451–458 (2009).
111. Skeaf, C. M. Feasibility of recommending certain replacement or alternative fats. *Eur. J. Clin. Nutr.* **63**, S34–S49 (2009).
112. Coombes, R. *Trans* fats: chasing a global ban. *BMJ* **343**, d5567 (2011).
113. Ratnayake, W. M. *et al. Trans* fatty acids: current contents in Canadian foods and estimated intake levels for the Canadian population. *J. AOAC Int.* **92**, 1258–1276 (2009).
114. Brownell, K. D. *et al.* The public health and economic benefits of taxing sugar-sweetened beverages. *N. Engl. J. Med.* **361**, 1599–1605 (2009).
115. Ng, S. W., Ni Mhurchu, C., Jebb, S. A. & Popkin, B. M. Patterns and trends of beverage consumption among children and adults in Great Britain, 1986–2009. *Br. J. Nutr.* http://dx.doi.org/10.1017/S0007114511006465.
116. Claro, R. M., Levy, R. B., Popkin, B. M. & Monteiro, C. A. Sugar-sweetened beverage taxes in Brazil. *Am. J. Public Health* **102**, 178–183 (2012).
117. Sturm, R., Powell, L. M., Chriqui, J. F. & Chaloupka, F. J. Soda taxes, soft drink consumption, and children's body mass index. *Health Aff. (Millwood)* **29**, 1052–1058 (2010).
118. Organisation for Economic Co-operation and Development (OECD). *Obesity Update 2012* [online], http://www.oecd.org/els/healthpoliciesanddata/49716427.pdf (2012).
119. Guo, X., Popkin, B. M., Mroz, T. A. & Zhai, F. Food price policy can favorably alter macronutrient intake in China. *J. Nutr.* **129**, 994–1001 (1999).
120. Zenk, S. N. *et al.* Fruit and vegetable access differs by community racial composition and socioeconomic position in Detroit, Michigan. *Ethn. Dis.* **16**, 275–280 (2006).
121. Brownell, K. D. & Ludwig, D. S. The Supplemental Nutrition Assistance Program, soda, and USDA policy: who benefits? *JAMA* **306**, 1370–1371 (2011).
122. Zhai, F. *et al.* What is China doing in policy-making to push back the negative aspects of the nutrition transition? *Public Health Nutr.* **5**, 269–273 (2002).
123. The Healthy Weight Commitment Foundation. *The Healthy Weight Commitment Foundation* [online], http://www.healthyweightcommit.org/ (2012).
124. Department of Health. Calories to be capped and cut. *Department of Health* [online], http://mediacentre.dh.gov.uk/2012/03/24/calories-to-be-capped-and-cut/ (2012).
125. Pan, X. R. *et al.* Effects of diet and exercise in preventing NIDDM in people with impaired glucose tolerance. The Da Qing IGT and Diabetes Study. *Diabetes Care* **20**, 537–544 (1997).
126. Tuomilehto, J. *et al.* Prevention of type 2 diabetes mellitus by changes in lifestyle among subjects with impaired glucose tolerance. *N. Engl. J. Med.* **344**, 1343–1350 (2001).
127. Knowler, W. C. *et al.* Reduction in the incidence of type 2 diabetes with lifestyle intervention or metformin. *N. Engl. J. Med.* **346**, 393–403 (2002).
128. Ramachandran, A. *et al.* The Indian Diabetes Prevention Programme shows that lifestyle modification and metformin prevent type 2 diabetes in Asian Indian subjects with impaired glucose tolerance (IDPP-1). *Diabetologia* **49**, 289–297 (2006).
129. Li, G. *et al.* The long-term effect of lifestyle interventions to prevent diabetes in the China Da Qing Diabetes Prevention Study: a 20-year follow-up study. *Lancet* **371**, 1783–1789 (2008).
130. Fang, X. H. *et al.* Prevention of stroke in urban China: a community-based intervention trial. *Stroke* **30**, 495–501 (1999).
131. Pekka, P., Pirjo, P. & Ulla, U. Influencing public nutrition for non-communicable disease prevention: from community intervention to national programme—experiences from Finland. *Public Health Nutr.* **5**, 245–251 (2002).
132. Puska, P., Vartiainen, E., Laatikainen, T., Jousilahti, P. & Paavola, M. (Eds) *The North Karelia Project: From North Karelia to National Action* (Helsinki University Printing House, Helsinki, 2009).
133. The EPODE Programme. *Epode European Network* [online], http://www.epode-european-network.com/ (2012).
134. Romon, M. *et al.* Downward trends in the prevalence of childhood overweight in the setting of 12-year school- and community-based programmes. *Public Health Nutr.* **12**, 1735–1742 (2009).
135. Borys, J.-M. *et al. Preventing Childhood Obesity* 42–44 (Lavoisier, Cachan, 2011).
136. Economos, C. D. *et al.* A community intervention reduces BMI z-score in children: Shape Up Somerville first year results. *Obesity (Silver Spring)* **15**, 1325–1336 (2007).
137. Gortmaker, S. L. *et al.* Reducing obesity via a school-based interdisciplinary intervention among youth: Planet Health. *Arch. Pediatr. Adolesc. Med.* **153**, 409–18 (1999).
138. Centers for Disease Control and Prevention. Obesity in K-8 students—New York city, 2006–07 to 2010–11 school years. *MMWR Morb. Mortal. Wkly Rep.* **60**, 1673–1678 (2011).
139. Kmietowicz, Z. EU law forces UK ministers to rethink food labelling. *BMJ* **344**, e3422 (2012).
140. Roberto, C. A., Larsen, P. D., Agnew, H., Baik, J. & Brownell, K. D. Evaluating the impact of menu labeling on food choices and intake. *Am. J. Public Health* **100**, 312–318 (2010).
141. Institute of Medicine. *School Meals: Building Blocks for Healthy Children* (National Academies Press, Washington D. C., 2009).
142. Rivera, J. A. *et al.* Beverage consumption for a healthy life: recommendations for the Mexican population [Spanish]. *Salud Pública Mex.* **50**, 173–195 (2008).
143. WHO/Europe. *Food and Nutrition Policy for Schools: a Tool for the Development of School Nutrition Programmes in the WHO European Region* (WHO Europe, Copenhagen, 2006).
144. Hawkes, C. Regulating and litigating in the public interest: regulating food marketing to young people worldwide: trends and policy drivers. *Am. J. Public Health* **97**, 1962–1973 (2007).
145. WHO. *Global Strategy on Diet, Physical Activity and Health* (WHO, Geneva, 2004).
146. Pucher, J., Buehler, R., Bassett, D. R. & Dannenberg, A. L. Walking and cycling to health: a comparative analysis of city, state, and international data. *Am. J. Public Health* **100**, 1986–1992 (2010).
147. New York City Department of Mental Health and Hygiene. *Physical activity and nutrition* [online], http://www.nyc.gov/html/doh/html/cdp/cdp_pan_pop.shtml.
148. Gortmaker, S. L. *et al.* Changing the future of obesity: science, policy, and action. *Lancet* **378**, 838-347 (2011).
149. Centers for Disease Control and Prevention (CDC). Ten great public health achievements —United States, 1900–1999. *MMWR Morb. Mortal. Wkly Rep.* **48**, 241–243 (1999).
150. Mello, M. M., Studdert, D. M. & Brennan, T. A. Obesity—the new frontier of public health law. *N. Engl. J. Med.* **354**, 2601–2610 (2006).

Author contributions

V. S. Malik researched the data for the article and wrote the manuscript. W. C. Willett and F. B. Hu both reviewed and edited the manuscript. All authors made substantial contributions to discussion of article content.

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