International Journal of Obesity (2004) 28, S2–S9
 0307-0565/04 $30.00
www.nature.com/ijo

PAPER

The nutrition transition: worldwide obesity dynamics and their determinants

BM Popkin[1]* and P Gordon-Larsen[1]

[1]*Department of Nutrition, Schools of Public Health and Medicine, University of North Carolina at Chapel Hill, Chapel Hill, NC, USA*

OBJECTIVE: This paper explores the major changes in diet and physical activity patterns around the world and focuses on shifts in obesity.
DESIGN: Review of results focusing on large-scale surveys and nationally representative studies of diet, activity, and obesity among adults and children.
SUBJECTS: Youth and adults from a range of countries around the world.
MEASUREMENTS: The International Obesity Task Force guidelines for defining overweight and obesity are used for youth and the body mass index $\geq 25\,kg/m^2$ and 30 cutoffs are used, respectively, for adults.
RESULTS: The nutrition transition patterns are examined from the time period termed the receding famine pattern to one dominated by nutrition-related noncommunicable diseases (NR-NCDs). The speed of dietary and activity pattern shifts is great, particularly in the developing world, resulting in major shifts in obesity on a worldwide basis. Data limitations force us to examine data on obesity trends in adults to provide a broader sense of changes in obesity over time, and then to examine the relatively fewer studies on youth. Specifically, this work provides a sense of change both in the United States, Europe, and the lower- and middle-income countries of Asia, Africa, the Middle East, and Latin America.
CONCLUSION: The paper shows that changes are occurring at great speed and at earlier stages of the economic and social development of each country. The burden of obesity is shifting towards the poor.
International Journal of Obesity (2004) **28,** S2–S9. doi:10.1038/sj.ijo.0802804

Keywords: youth obesity; nutrition transition; obesity trend

Introduction

Over the past 15 y, there has been increasing evidence that the structure of dietary intakes and the prevalence of obesity around the developing world have been changing at an increasingly rapid pace.[1] In many ways, these shifts are a continuation of large-scale changes that have occurred repeatedly over time; however, we will assert and show that the changes facing low- and moderate-income countries appear to be very rapid. While initially these shifts were felt to be limited to higher-income urban populations, it is increasingly clear that these are much broader trends affecting all segments of society.

Two historic processes of change occur simultaneously with, or precede, the 'nutrition transition'. One is the demographic transition—the shift from a pattern of high fertility and mortality to one of low fertility and mortality (typical of modern industrialized countries). The second is the epidemiological transition, first described by Omran:[2] the shift from a pattern of high prevalence of infectious disease—associated with malnutrition, periodic famine, and poor environmental sanitation—to one of high prevalence of chronic and degenerative disease—associated with urban–industrial lifestyles.[3]

The nutrition transition is closely related to the demographic and epidemiologic transitions. Large shifts have occurred in diet and in physical activity patterns, particularly in the last one or two decades of the 20th century. Modern societies seem to be converging on a diet high in saturated fats, sugar, and refined foods but low in fiber—often termed the 'Western diet'—and on lifestyles characterized by lower levels of activity. These changes are reflected in nutritional outcomes, such as changes in average stature, body composition, and morbidity.

*Correspondence: Professor BM Popkin, Carolina Population Center, CB &hash; 8120 University Square, University of North Carolina at Chapel Hill, Chapel Hill, NC 27516-3997, USA.
E-mail: POPKIN@UNC.EDU

The last three stages of the nutrition transition are described in more detail in Figure 1. In Stage 3, famine begins to recede as income rises. In Stage 4, changes in diet and activity pattern lead to the emergence of new disease problems and increased disability. In Stage 5, behavioral change begins to reverse the negative tendencies and make possible a process of 'successful aging'.[4,5] The changes are all driven by a range of factors, including urbanization, economic growth, technical change, and culture. For convenience, the patterns can be thought of as historical developments; however, 'earlier' patterns are not restricted to the periods in which they first arose, but continue to characterize certain geographic and socioeconomic (SES) subpopulations. Elsewhere we have laid out the full set of nutrition transition stages in more detail.[6,7]

On a global basis, there are several themes related to obesity that we will summarize. The first is the general shift toward obesity that represents a global problem rather than one centered in a few high-income countries. The second is the rapid increase in obesity found in lower- and middle-income developing countries—a rate of change that appears to be greater than that found in higher-income countries. The third is the shift in the burden of obesity toward the poor on a worldwide basis. We present the limited comparable data on trends in adolescent obesity across the globe, with specific attention to the link between obesity and economic and social development.

Dietary changes around the world are rapid!

The diets of the developing world are shifting rapidly, particularly with respect to fat, caloric sweeteners, and animal source foods (ASF).[1,8]

Edible oil

Elsewhere we have provided evidence of the rapid increases in edible oil at the national and household level throughout the developing world. In many developing countries, dietary change has begun with major increases in domestic production and imports of oilseeds and vegetable oils—rather than animal source products or caloric sweeteners. For instance, between 1991 and 1996/7, global production of vegetable fats and oils rose from 60 to 71 million metric tons.[9] In contrast, the production of visible animal fats (butter and tallow) has remained steady at approximately 12 million metric tons. Principal vegetable oils include soybean, sunflower, rapeseed, palm, and groundnut oil. With the exception of groundnut oil, global availability of each has approximately tripled between 1961 and 1990. While the broader macroeconomic shifts that affected this increase in edible vegetable fat intake—namely, edible vegetable fat prices, supply, and consumption—is unique because it affected rich and poor countries equally, the net impact is relatively much greater on low-income countries.[10,11]

Caloric sweeteners

Sugar is the world's predominant sweetener. It is not clear exactly when sugar became the world's principal sweetener—most likely in the 17th or 18th century—as the New World began producing large quantities of sugar at reduced prices.[12,13] We use the term caloric sweetener instead of added sugar, as there is such a range of nonsugar products used today. High-fructose corn syrup is a prime example, as it is the sweetener used in all US soft drinks. The name 'sweeteners' includes products used for

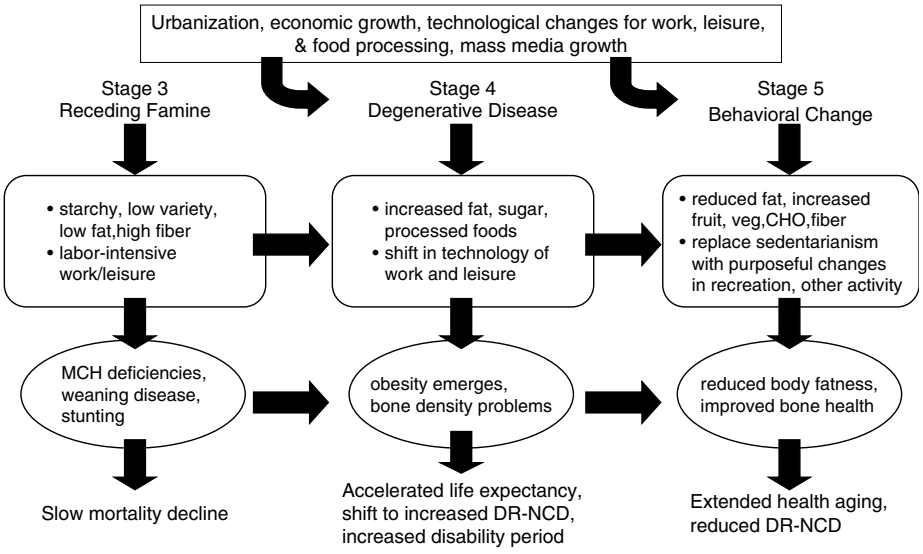

Figure 1 Stages of the nutrition transition.

sweetening derived either from sugar crops, cereals, fruits, milk, or produced by insects. This category includes a wide variety of monosaccharides (glucose and fructose) and disaccharides (sucrose and saccharose), which exist either in a crystallized state as sugar or in thick liquid form as syrups. Included in sweeteners are maple sugar and syrups, caramel, golden syrup, artificial and natural honey, maltose, glucose, dextrose, glucose (also known as high-fructose corn syrup), other types of fructose, sugar confectionery, and lactose.

In the last several decades, increasingly larger quantities of cereals (primarily maize) have been used to produce sweeteners derived from starch. The overall trends show a large increase in caloric sweetener consumed.[14] In 2000, 306 kcal were consumed per person per day, about a third more than in 1962; caloric sweeteners also accounted for a larger share of both total energy and total carbohydrates consumed. Not surprisingly, we have shown that all measures of caloric sweetener increase significantly as gross national product (GNP) per capita of the country and urbanization increase. However, the interaction between income growth and urbanization is important. Figure 2 shows the relationship between the proportion of energy from different food sources and GNP, for two different levels of urbanization; see Drewnoswski and Popkin[10] for a description of the analysis. In the less urbanized case (panel A), the share of sweeteners increases sharply with income, from about 5% to about 15%. In the more urbanized case (panel B), the share (over 15%) is much higher at lower income and decreases with income. The analysis confirms previous observations that diets of people living in urban areas are distinct from those of their rural counterparts.[15]

Animal source foods

The revolution in ASF refers to the increase in demand and production of meat, fish, and milk in low-income developing countries. Delgado at International Food Policy Research Institutes (IFPRIs) has studied this issue extensively in a number of seminal reports and papers[16,17] Most of the world's growth in production and consumption of these foods comes from the developing countries; thus, developing countries will produce 63% of meat and 50% of milk in 2020. It is a global food activity, transforming the grain markets for animal feed. It also leads to resource degradation, rapid increases in feed grain imports, rapid concentration of production and consumption, and social change.

China provides an example of the shift in intake of ASF. The results are presented in depth elsewhere.[8] In the past 50 y, using the per capita data from the nationally representative household survey series in China, we find that annual consumption of animal foods more than tripled—from a very low-level consumption of 11 kg per capita in 1952 to 38 kg per capita in 1992.[8] There was a slow rate of increase prior to 1979, but thereafter, the rate of increase was much higher. From 1952 to 1979, intake increased only by 5.6 kg (0.2 kg annually), while it increased by 21 kg (1.6 kg annually) between 1979 and 1992. Of the subcomponents, meat and meat products increased from 8.4 to 20.3 kg, poultry and games from 0.6 to 2.3 kg, fish from 3.2 to 7.3 kg, and eggs from 2.0 to 7.8 kg per capita, per year. Urban residents' intake of ASF increased to 65.3 kg per capita in 1999.

Using in-depth individual intake data from the China Health and Nutrition Survey (CHNS), we get a clear picture of the shift in actual daily dietary intake toward increased animal foods. Urban residents' intake of animal foods per

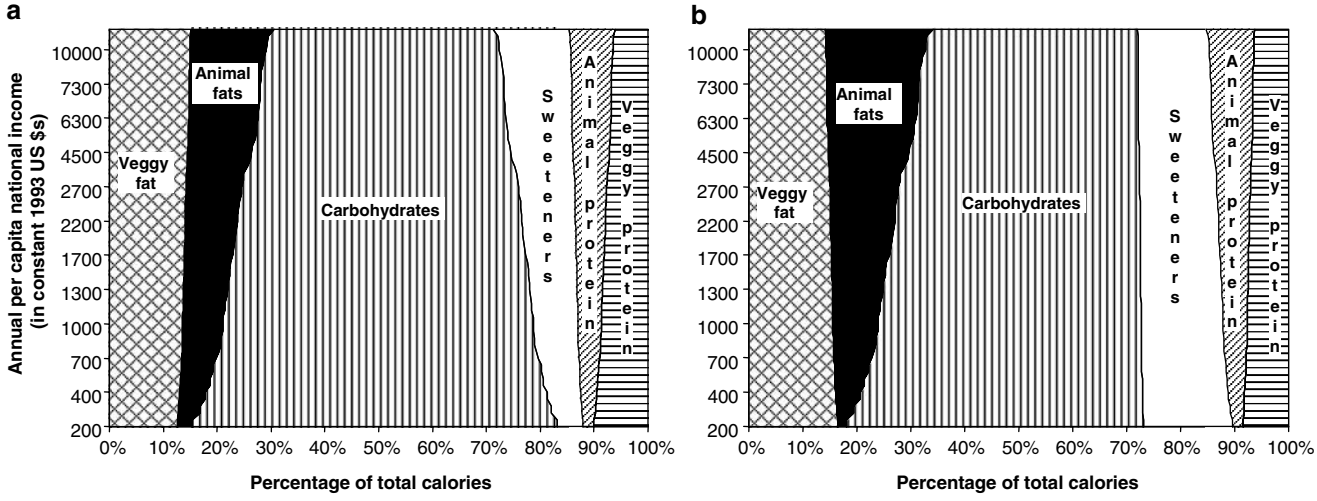

Figure 2 Relationship between the proportion of energy from each food source and GNP per capita and urbanization. (a) The proportion of the population residing in urban areas is placed at 25%, 1990. (b) The proportion of the population residing in urban areas is placed at 75%, 1990.

capita, per day in 1997 was higher than rural residents (178.2 g for urban *vs* 116.7 g for rural), and also showed a larger increase (46.7 g *vs* 36.8 g) from 1989 to 1997. The amount and growth of intake of animal foods was positively associated with income levels. Intake in the low-income group was 77.6 g per capita, per day in 1997, an increase of 18.6 g, while it was 123.2 and 19.6 g in the mid-income group, and 191.7 and 64.8 g per capita, per day for the high-income group. The intake level and the increase in the high-income group from 1989 to 1997 were almost three times that in the low-income group.

The US case as an example of developed country dynamics

The dietary trends in the United States are more complex than those found in the developing world. In the United States, daily caloric intake appears to be increasing—primarily from energy-dense, nutrient-poor foods and an increase in snacks.[18–23] More meals are being consumed away from home[18–20,22] and portion sizes offered in restaurants have increased dramatically.[14,18,24] There have been significant increases in salty snacks, fast foods,[18–20] and added caloric sweeteners.[14,25] Fast foods generally are more energy dense, but lack many critical nutrients,[26,27] and might be linked with obesity.[28–33] Fruit and vegetable consumption remains far below the recommended levels.[14,18]

Physical activity changes appear to be changing rapidly!

There are several linked changes in physical activity occurring jointly. One is a shift away from the high-energy expenditure activities such as farming, mining, and forestry towards the service sector. Elsewhere we have shown this large effect.[34] Reduced energy expenditures in the same occupation are a second change. Other major changes relate to the modes of transportation and activity patterns during leisure hours. China again provides interesting illustrations. Table 1 shows that the proportion of urban adults (male and female) working in occupations where they participate in vigorous activity patterns has decreased. In rural areas, however, there has been a shift for some towards increased physical activity linked to holding multiple jobs and more intensive effort. For rural women, there is a shift towards a larger proportion engaged in more energy-intensive work, but there are also sections where light effort is increasing. In contrast, for rural men there is a small decrease in the proportion engaged in light work effort.

Table 1 Force distribution among Chinese adults, aged 20–45 y (China Health and Nutrition Survey 1989, 1997)

		Light (%)		*Vigorous (%)*	
		1989	*1997*	*1989*	*1997*
Urban	Male	32.7	38.2	27.1	22.4
	Female	36.3	54.1	24.8	20.8
Rural	Male	19	18.7	52.5	59.9
	Female	19.3	25.5	47.4	60

Source: Du *et al.*[11]

In China, 14% of households acquired a motorized vehicle between 1989 and 1997. In one study, we showed that the odds of being obese were 80% higher ($P<0.05$) in households for men and women who owned a motorized vehicle compared to those who did not own a vehicle.[35]

Television ownership has skyrocketed in China, leading to greater inactivity during leisure time.[11] Among youth in the United States and Mexico, TV viewing is quite extensive but it is much lower in China, Russia, and the Philippines. The average child in the United States today spends more than 3 h a day watching television or playing video games and another 3 h with other forms of media such as movies and prerecorded music.[36] So far, children in China spend significantly less time than their US counterparts with such sedentary media, but if US patterns prevail, we should expect that Chinese children will spend more time attending to the media in the future. Similarly, CHNS data for 1997 found that children aged 6–12 y watched TV at an average of 0.77 h per day, with slightly lower levels, 0.52 h per day, in children aged 13–18 y; overall, about 9% reporting watching TV for two or more hours per day. The overall physical activity pattern data are more limited among the youth. We have described physical activity patterns of youth in Russia, China, and the Philippines in a series of papers. In each case, we have found that walking to school is a major source of overall physical activity.[37–40] We have also found quite meaningful differences between countries. For instance, in the Philippines, youth of all ages are actively engaged in activities such as cleaning, washing, and other measures of home production, while in China, children are essentially excluded from such activities and study much more.[40]

Obesity patterns and trends

It is important to first present a few key issues related to adults, allowing us to provide a full picture of obesity in children, as there is limited data on children available.

Shifts in adult obesity are occurring across the globe

We have shown elsewhere that the current levels of overweight in countries as diverse as Mexico, Egypt, and South Africa are shown to be equal or greater than those in the United States.[7] Moreover, the rate of change in obesity in lower- and middle-income countries is shown to be much greater than in higher-income countries; see Popkin[7] for an overview. The survey data sets used are nationally representative comparable data for a number of countries for current levels of overweight and obesity prevalence and their rates of change. Figure 3 (panel A) presents the level of obesity and

overweight in several illustrative countries (Brazil, Mexico, Egypt and Morocco, South Africa, Thailand, and China). Most interesting is the fact that many of these countries with quite high overweight levels are very low-income. Moreover, it probably surprises many people that the levels of obesity of several countries—all with much lower income levels than the United States—are so high.

There is enormous heterogeneity in the patterns, trends, and timing of obesity among developing countries. Many countries in Latin America began their transition earlier in the past century and certainly entered the nutrition-related noncommunicable disease (NR-NCD) stage of the transition far earlier than did other regions. However, there is enormous heterogeneity in countries, such as Haiti, and subpopulations in Central America are still in the receding famine period. Moreover, some countries, such as Mexico, really experienced an accelerated transition in the 1990s.[41] The Middle East, North Africa, and Asia appear to have begun their transition at a much later date as have most other countries in the developing world except for the Western Pacific nations.

Changes in the developing world are faster than in higher-income countries!

Figure 3 (panel B) shows how quickly overweight and obesity status have emerged as a major public health problem in some of these countries. Compared with the United States and European countries, where the annual increase in the prevalence of overweight and obesity among adult men and women is about 0.25 for each, the rates of change are very high in Asia, North Africa, and Latin America—two to five times greater than in the United States.

The burden of obesity has shifted to the poor!

Elsewhere we have shown that a large number of low- and moderate-income countries already have a greater likelihood that adults residing in lower-income or lower-educated households are overweight and obese, relative to adults in higher-income or higher-educated households.[42,43] Both papers used 37 nationally representative surveys of women aged 20–50 y. One showed that countries with a GNP per capita over about $2500 are likely to have a burden of obesity greater among the poor. Belonging to the lower-SES group confers strong protection against obesity in low-income economies, can reduce or increase obesity in lower-middle income economies and is a systematic risk factor for obesity in upper-middle income developing economies. A multilevel logistic model—including an interaction term between the country's GNP and each woman's SES—indicates that obesity starts to fuel health inequities in the developing world when the GNP reaches a value of about US$2500 per capita. Examples of countries above the US$2500 per capita income level—those upper-middle income developing economies with higher obesity among the lower-SES groups include Mexico, Brazil, Turkey, and South Africa.

Child and youth obesity prevalence and trends

A study of adolescent obesity dynamics was undertaken across four longitudinal studies.[44] Nationally representative data from Brazil (1975 and 1997), Russia (1992 and 1998), the United States (NHANES I (1971–1974) and NHANES III (1988–1994)), and nationwide survey data from China (1991 and 1997) were used. Overweight is defined using the sex–age-specific body mass index (BMI) cutoffs recommended by the International Obesity Task Force (IOTF).[45]

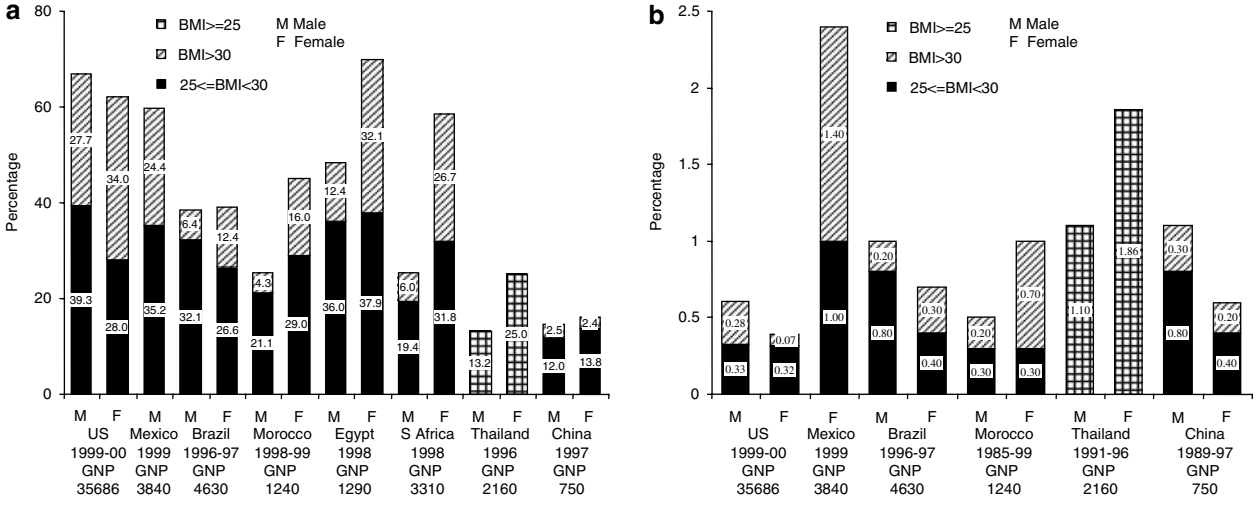

Figure 3 Obesity patterns and trends across the world, adults aged 20 y and older. (a) Prevalence rates. (b) Obesity trends (the annual percentage point increase in prevalence).

Overweight prevalence (Figure 4) has increased in Brazil (from 4.2 to 14.3%), China (from 6.4 to 7.7%), and the United States (from 15.4 to 25.6%). In Russia, overweight prevalence decreased (from 15.6 to 9.0%). The annual increase rates of overweight prevalence are 0.5% (Brazil), 0.2% (China), −1.1% (Russia), and 0.4% (United States).

The trends and current prevalence of overweight vary substantially across the four countries we examined and seem to show a slower increase in child obesity than the rate of increase in obesity experienced by adults in these countries. The burden of nutritional problems is shifting from energy imbalance deficiency to excess among older children and adolescents in Brazil and China. These changes and differences may relate to changes and differences in key environmental factors across countries. For example, the GDP tripled in the United States and Brazil, but increased by greater than 10-fold in China during this time.[44] Conversely, Russia saw a worsening of the economy and a decline in living standards (eg decline of living standards, including a decrease of food consumption and production). Over the past three decades, the percentage of older children and adolescents who were overweight tripled in Brazil and almost doubled in the United States. We found that the overweight prevalence was considerably higher in children than in adolescents in Russia, Brazil, and China but not in the United States.[44] The far greater proportion of adolescent overweight prevalence in the United States stands out. It is possible that this relates partly to our use of the IOTF reference, but these differences may be far too great to be explained by the use of this reference.

Similar to adults, the changes in youth obesity in these four countries vary across levels of household income. Over the past two decades, the prevalence of overweight in Brazil increased most quickly in high-SES groups, but in the United States the increase was greatest in low-SES groups.[44] In addition, the prevalence of overweight was much higher in urban areas than in rural areas in Russia and the United States.

Childhood and adolescent obesity patterns across Europe

A recent comparative study conducted across Europe, presented in depth in other studies, also utilized the IOTF cutoff criteria for overweight.[45,46] These are not nationally representative studies, but all use BMIs based on anthropometric measures—not self-reported weight and height—that are representative samples of the general population of either the country or a region of it. Four surveys (those for Belgium, Croatia, the Netherlands, and Switzerland) did not provide estimates of overweight using the IOTF criteria and the authors used other methods to estimate the proportion of the sample that would exceed the IOTF cutoff points. This study, as well as others, has shown that the prevalence of obesity has risen dramatically in many countries across Europe.[46,47] Among children (ages 7–11 y), overweight differs across Europe from France (19%), the United Kingdom (20%), Sweden (18%), and Denmark (15%) in Western and Northern Europe to Russia (10%) and Poland (18%) in the Eastern bloc and to Spain (34%), Italy (36%), and Malta (35%) in Southern Europe.[47] Adolescent (14–17 y) overweight is similar, with particularly high levels in the United Kingdom (21%) and Southern Europe (Spain (21%), Greece (22%), and Cyprus (23%)). Guillame and Lissau[47] postulate many reasons for these variations. For example, the North–South trend is clearly seen and the lower prevalence in Central and Eastern Europe occurs in countries whose economies suffered from recession during the economic and political transition of the 1990s.

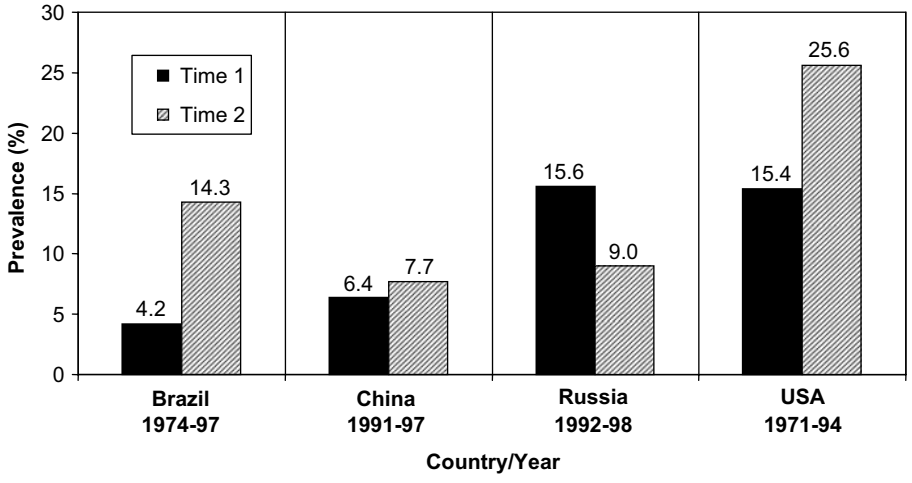

Figure 4 Child overweight trends (using IOTF cutoffs).

Shifts in age-specific time trends

There are few longitudinal studies that follow different age groups at the same time using a mixed cohort study. Studies of both dietary and body composition trends seem to indicate an increase in rates of change across the world. This has been found in studies of income and price changes on the structure of the Chinese diets as well as with obesity trends in the United States. In China, two studies have shown that shifts towards intake of higher fat foods and higher fat diets have accelerated changes in income.[48,49] In each case, longitudinal analysis was used to show a significant increase in the impact of income on diet.

In a longitudinal study in which over 9000 US young adults born between 1957 and 1964 were resurveyed 13 times over the span of two decades, it was found that more than 25% were obese by age 35 y.[50] Timing of obesity onset was highest among black females, moderate in Hispanic females, and lowest in white females, while among males the highest onset was seen for Hispanic males. In addition, McTigue *et al*[50] found a large secular weight trend: people born in later calendar years tended to have larger age-specific BMI. In every case in which the same age was sampled for both birth cohorts, the 1957-born group had a lower mean BMI than the 1964-born group. The intermediate birth cohorts had intermediate-range mean BMI values.

United States case study—insights into current dynamics in the higher-income world

Gordon-Larsen *et al*[51] sought to examine patterns of change in obesity among US white, black, Hispanic, and Asian teens as they transition from adolescence to young adulthood. At baseline (1996) obesity prevalence (using IOTF cut points) was 10.9%. After 5 y, a substantial proportion of the adolescents nonobese at baseline had become obese (12.7% incidence) and remained obese (9.4% obesity maintenance), with a small proportion moving from obese to nonobese (1.6% reversal). Obesity incidence was especially high among non-Hispanic black (18.4%) and Hispanic females (15.8%) relative to white females (12.5%), as was obesity maintenance among black (16.1%) and Hispanic (10.9%) females relative to white females (8.5%). Importantly, these data represent approximately 15.1 million 13- to 20-y-old US schoolchildren. Thus, in the 5-y study period more than 1.9 million US adolescents became obese, more than 1.3 million adolescents remained obese, while only approximately one-quarter of a million adolescents became nonobese.

Conclusion

We have summarized the profound global shift in obesity. The high obesity prevalence in adolescents is shown to be persistent into adulthood with high incidence in the transition to adulthood. We see from the US case that the increase in obesity from adolescence to adulthood is tremendous. Other countries following this trajectory are likely to see substantial adult obesity and its associated comorbidities if this trajectory is not curbed.

In addition, current data indicate that the levels of adult obesity far exceed those of children across all regions of the world. In addition, it seems that rapid increases in child and adolescent obesity have emerged in recent years, but they still do not equal the rate of increase found among adults.

We have briefly summarized some of the broader trends in diet in the developing and developed world with a focus on case studies from China and the United States. Underlying these trends are the major and rapid shifts in diets of the developing world, particularly with respect to greater intake of fat, caloric sweeteners, and ASF. In addition, declines in physical activity in leisure, transportation, and work associated with modernization play a substantial role. Greater amounts of sedentary behavior time associated with the worldwide use of mass media compound these effects.

References

1 Popkin BM. The shift in stages of the nutrition transition in the developing world differs from past experiences!. *Public Health Nutr* 2002; **5**: 205–214.
2 Omran AR. The epidemiologic transition: a theory of the epidemiology of population change'. *Milbank Mem Fund Q* 1971; **49**: 509–538.
3 Olshansky SJ, Ault AB. The fourth stage of the epidemiologic transition: the age of delayed degenerative diseases'. *Milbank Mem Fund Q* 1986; **64**: 355–391.
4 Manton KG, Soldo BJ. Dynamics of health changes in the oldest old: new perspective and evidence'. *Milbank Mem Fund Q* 1985; **63**: 206–285.
5 Crimmins EM, Saito Y, Ingegneri D. Changes in life expectancy and disability-free life expectancy in the United States. *Popul Dev Rev* 1989; **15**: 235–267.
6 Popkin BM. The nutrition transition in low-income countries: an emerging crises. *Nutr Rev* 1994; **52**: 285–298.
7 Popkin BM. An overview on the nutrition transition and its health implications: the Bellagio meeting. *Public Health Nutr* 2002; **5**: 93–103.
8 Popkin BM, Du S. Dynamics of the nutrition transition toward the animal foods sector in China and its implications: a worried perspective. *J Nutr* 2003; **133**: 3898S–3906S.
9 US Department of Agriculture. *World Agricultural Supply and Demand Estimates (WASDE-315). Table: Vegetable Oil Consumption Balance Sheets (in million metric tons), FAS Online*. USDA: Washington, DC; 1997.
10 Drewnoswski A, Popkin BM. The nutrition transition: new trends in the global diet. *Nutr Rev* 1997; **55**: 31–43.
11 Du S, Lu B, Zhai F, Popkin BM. The nutrition transition in China: a new stage of the Chinese diet. In: Caballero B, Popkin BM (eds) *The Nutrition Transition: Diet and Disease in the Developing World*. Academic Press: London; 2002. pp 205–222.
12 Galloway JH. Sugar. In: Kiple KF, Ornelas KC (eds) *The Cambridge World History of Food*, Vol. I. Cambridge University Press: New York; 2000.
13 Mintz S. Time, sugar, and sweetness. In: Counihan C, Van Esterik P (eds). *Food and Culture: A Reader*. Routledge: New York; 1977.
14 Popkin BM, Nielsen SJ. The sweetening of the world's diet. *Obes Res* 2003; **11**: 1325–1332.
15 Mendez M, Popkin BM. Globalization, urbanization and nutritional change in the developing world. *Electron J AgricDev Econ*, (in press).

16 Delgado CL. Rising consumption of meat and milk in developing countries has created a new food revolution. *J Nutr* 2003; **133**: 3907S–3910S.
17 Delgado CL, Rosegrant MW, Steinfeld H, Ehui SK, Courbois C. *Livestock to 2020: The Next Food Revolution*. International Food Policy Research Institute; Food and Agriculture Organization of the United Nations (FAO); International Livestock Research Institute (ILRI): Washington DC, Rome, Nairobi, Kenya; 1999.
18 French S, Story M, Neumark-Sztainer D, Fulkerson JA, Hannan P. Fast food restaurant use among adolescents: associations with nutrient intake, food choice, and behavioral and psychosocial variables. *Int J Obes Relat Metab* 2001; **25**: 1823–1833.
19 Nielsen S, Siega-Riz A, Popkin BM. Trends in energy intake in the US between 1977 and 1996: similar shifts seen across age groups. *Obes Res* 2002; **10**: 370–378.
20 Nielsen S, Siega-Riz A, Popkin BM. Trends in food locations and sources among adolescents and young adults. *Prev Med* 2002; **35**: 107–113.
21 Haines P, Hama M, Guilkey DK, Popkin BM. Weekend eating in the United States is linked with greater energy, fat and alcohol intake. *Obes Res* 2003; **11**: 945–949.
22 Jeffery R, Utter J. The changing environment and population obesity in the United States. *Obes Res* 2003; **11**: 12S–22S.
23 Nielsen S, Popkin BM. Patterns and trends in portion sizes, 1977–1998. *JAMA* 2003; **289**: 450–453.
24 Young LR, Nestle M. The contribution of expanding portion sizes to the US obesity epidemic. *Am J Public Health* 2002; **92**: 246–249.
25 Bray GA, Nielsen SJ, Popkin BM. Consumption of high-fructose corn syrup in beverages may play a role in the epidemic of obesity. *Am J Clin Nutr* 2004; **79**: 537–543.
26 Guthrie J, Lin B, Frazao E. Role of food prepared away from home in the American diet, 1977–78 versus 1994–96: changes and consequences. *J Nutr Educ Behav* 2002; **34**: 140–150.
27 Paeratakul S, Ferdinand DP, Champagne CM, Ryan DH, Bray GA. Fast-food consumption among US adults and children: dietary and nutrient intake profile. *J Am Diet Assoc* 2003; **103**: 1332–1338.
28 Bowman SA, Gortmaker SL, Ebbeling CB, Pereira MA, Ludwig DS. Effects of fast-food consumption on energy intake and diet quality among children in a National Household Survey. *Pediatrics* 2004; **113**: 112–118.
29 McCrory M, Fuss P, Hays NP, Vinken AG, Greenberg AS, Roberts SB. Overeating in America: association between restaurant food consumption and body fatness in healthy men and women ages 19 to 80. *Obes Res* 1999; **7**: 564–571.
30 French S, Harnack L, Jeffery RW. Fast food restaurant use among women in the Pound of Prevention study: dietary, behavioral and demographic correlates. *Int J Obes Relat Metab Disord* 2000; **24**: 1353–1359.
31 Ma Y, Bertone E, Stanek EJ, Reed GW, Hebert JR, Cohen NL, Merriam PA, Ockene IS. Association between eating patterns and obesity in a free-living adult population. *Am J Epidemiol* 2003; **158**: 85–92.
32 Nicklas T, Yang S, Baranowski T, Zakeri I, Berenson G. Eating patterns and obesity in children: the Bogalusa Heart Study. *Am J Prev Med* 2003; **25**: 9–16.
33 Thompson O, Ballew C, Resnicow K, Must A, Bandini LG, Cyr H, Dietz WH. Food purchased away from home as a predictor of change in BMI *z*-scores among girls. *Int J Obes Relat Metab* 2003; **28**: 282–289.
34 Popkin BM. Urbanization, lifestyle changes and the nutrition transition. *World Development* 1999; **27**: 1905–1916.
35 Bell AC, Ge K, Popkin BM. The road to obesity or the path to prevention? Motorized transportation and obesity in China. *Obes Res* 2002; **10**: 277–283.
36 Roberts DF, Foehr UG. *Kids and Media in America*. Cambridge University Press: Cambridge; 2004.
37 Levin S, Ainsworth BE, Kwok CW, Addy CL, Popkin BM. Patterns of physical activity among Russian youth: the Russian Longitudinal Monitoring Survey. *Eur J Public Health* 1999; **9**: 166–173.
38 Tudor-Locke C, Ainsworth BE, Popkin BM. Active commuting to school: an overlooked source of children's physical activity? *Sports Med* 2001; **31**: 309–313.
39 Tudor-Locke C, Ainsworth BA, Adair LS, Popkin BM. Physical activity in Filipino youth: the Cebu Longitudinal Health and Nutrition Survey. *Int J Obes Relat Metab* 2003; **27**: 181–190.
40 Tudor-Locke C, Ainsworth BE, Adair LS, Du S, Popkin BM. *Comparison of Physical Activity and Inactivity Patterns in Chinese and Filipino Youth* 2004 (in press).
41 Rivera JA, Barquera S, Campirano F, Campos I, Safdie M, Tovar V. Epidemiological and nutritional transition in Mexico: rapid increase of non-communicable chronic diseases and obesity. *Public Health Nutr* 2002; **5**: 113–122.
42 Monteiro CA, Conde WL, Lu B, Popkin BM. *Is Obesity Fuelling Inequities in Health in the Developing World?* University of North Carolina Manuscript: Chapel Hill, NC; 2004.
43 Mendez MA, Monteiro CA, Popkin BM. *Overweight Now Exceeds Underweight Among Women in Most Developing Countries!* University of North Carolina Manuscript: Chapel Hill, NC; 2004.
44 Wang Y, Monteiro C, Popkin BM. Trends of overweight and underweight in children and adolescents in the United States, Brazil, China, and Russia. *Am J Clin Nutr* 2002; **75**: 971–977.
45 Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. Establishing a standard definition for child overweight and obesity worldwide: international survey. *BMJ* 2000; **320**: 1240–1243.
46 Lobstein T, Frelut M-L. Prevalence of overweight among children in Europe. *Obes Rev* 2003; **4**: 195–200.
47 Guillame M, Lissau I. Epidemiology. In: Burniat W, Cole T, Lissau I, Poskitt EME (eds) *Child and Adolescent Obesity: Causes and Consequences, Prevention and Management*. Cambridge University Press: Cambridge; 2002. pp 28–49.
48 Du S, Mroz TA, Zhai F, Popkin BM. Rapid income growth adversely affects diet quality in China—particularly for the poor!? *Soc Sci Med* 2004; **59**: 1505–1515.
49 Guo X, Mroz TA, Popkin BM, Zhai F. Structural changes in the impact of income on food consumption in China, 1989–1993. *Econ Dev Cultural Change* 2000; **48**: 737–760.
50 McTigue KM, Garrett JM, Popkin BM. The natural history of obesity: weight change in a large US longitudinal survey. *Ann Intern Med* 2002; **136**: 857–864.
51 Gordon-Larsen P, Adair LS, Nelson MC, Popkin BM. Five-year obesity incidence in the transition period between adolescence and adulthood: the National Longitudinal Study of Adolescent Health. *Am J Clin Nutr* 2004; **80**: 569–575.