Global nutrition dynamics: the world is shifting rapidly toward a diet linked with noncommunicable diseases[1–3]

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ABSTRACT

Global energy imbalances and related obesity levels are rapidly increasing. The world is rapidly shifting from a dietary period in which the higher-income countries are dominated by patterns of degenerative diseases (whereas the lower- and middle-income countries are dominated by receding famine) to one in which the world is increasingly being dominated by degenerative diseases. This article documents the high levels of overweight and obesity found across higher- and lower-income countries and the global shift of this burden toward the poor and toward urban and rural populations. Dietary changes appear to be shifting universally toward a diet dominated by higher intakes of animal and partially hydrogenated fats and lower intakes of fiber. Activity patterns at work, at leisure, during travel, and in the home are equally shifting rapidly toward reduced energy expenditure. Large-scale decreases in food prices (eg, beef prices) have increased access to supermarkets, and the urbanization of both urban and rural areas is a key underlying factor. Limited documentation of the extent of the increased effects of the fast food and bottled soft drink industries on this nutrition shift is available, but some examples of the heterogeneity of the underlying changes are presented. The challenge to global health is clear. *Am J Clin Nutr* 2006;84:289–98.

KEY WORDS Nutrition transition, global obesity, edible oils, caloric sweeteners, physical inactivity

WHAT IS THE NUTRITION TRANSITION?

Humankind has faced major shifts in dietary and physical activity patterns and body composition since Paleolithic man emerged on Earth. Human diet and nutritional status have undergone a sequence of major shifts among characteristic states—defined as broad patterns of food use and corresponding nutrition-related disease. Over the past 3 centuries, the pace of dietary change appears to have accelerated to varying degrees in different regions of the world. The concept of the nutrition transition focuses on large shifts in diet and activity patterns, especially their structure and overall composition. These changes are reflected in nutritional outcomes, such as changes in average stature and body composition. Furthermore, dietary and activity pattern changes are paralleled by major changes in health status and by major demographic and socioeconomic changes.

One needs to be concerned with food supply, which relates to agricultural systems and agricultural technology, as well as with the factors that affect the demand for and use of food. The latter include economic resources, demographic patterns, and various cultural and knowledge factors associated with food choice, disease patterns, and sociologic considerations (eg, the role of women and family structure). Similarly, equally important changes affect how we move, work at home and in the marketplace, and change our leisure activity patterns.

This shift toward increased obesity and noncommunicable diseases (NCDs) is only the latest pattern of this transition. The 5 patterns of the nutrition transition are presented in **Table 1** (1). The first pattern, which is linked with hunter-gather societies and is often called the Paleolithic pattern (but covers a longer period), was one in which the diet was very healthy, but infectious diseases and other natural causes resulted in a very short life span. The second pattern, when modern agriculture and a period of famine emerged, was one in which nutritional status worsened. Most attention is focused on nutrition shifts in the last 3 patterns, which are generally the ones represented by most of the global population today (**Figure 1**). In pattern 3, famine begins to recede as income rises. In pattern 4, changes in diet and activity patterns lead to the emergence of new diseases and increases disability. In pattern 5, behavioral change begins to reverse the negative tendencies of the preceding patterns and enable a process of successful aging (3, 4). A range of factors (including urbanization, economic growth, technical change, and culture) drives all the changes. 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 subpopulations.

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TABLE 1
Characteristics of the 5 patterns of the nutrition transition

	Transition profile				
	Pattern 1: collecting food	Pattern 2: famine	Pattern 3: receding famine	Pattern 4: degenerative disease	Pattern 5: behavioral change
Nutrition profile					
Diet	Plants, low-fat wild animals, varied diet	Cereals predominant, diet less varied	Fewer starchy staples; more fruit, vegetables, animal protein; low variety continues	More fat (especially from animal products), sugar, processed foods; less fiber	Higher-quality fats, reduced refined carbohydrates, more whole grains, fruit, vegetables
Nutritional status	Robust, lean population; few nutritional deficiencies	Children and women suffer most from low fat intake, nutritional-deficiency diseases emerge, stature declines	Continued MCH[1] nutrition problems, many deficiencies disappear, weaning diseases emerge, stature grows	Obesity, problems for elderly (bone health, etc), many disabling conditions	Reduction in body fat and obesity, improvement in bone health
Economy	Hunter-gatherers	Agriculture, animal husbandry, homemaking begin; shift to monocultures	Second agricultural revolution (crop rotation, fertilizer), Industrial Revolution, women join labor force	Fewer jobs with heavy physical activity, service sector and mechanization, household technology revolution	Service sector mechanization and industrial robotization dominate, increase in leisure exercise offsets sedentary jobs
Household production	Primitive, onset of fire	Labor-intensive, primitive technology begins (clay cooking vessels)	Primitive water systems, clay stoves, cooking technology advances	Household technology mechanizes and proliferates	Significant reduction in food preparation costs as a result of technologic change
Income and assets	Subsistence, primitive stone tools	Subsistence, few tools	Increases in income disparity and agricultural tools industrialization	Rapid growth in income and income disparities, technology proliferation	Decrease in income growth, increase in home and leisure technologies
Demographic profile					
Mortality and fertility	Low fertility, high mortality, low life expectancy	Age of Malthus; high natural fertility, short life expectancy, high infant and maternal mortality	Mortality declines slowly, then rapidly; fertility static, then declines; small, cumulative population growth, which later explodes	Life expectancy hits unique levels (ages 60–70), huge decline and fluctuations in fertility (eg, postwar baby boom)	Life expectancy extends to ages 70 and 80 y, disability-free period increases
Morbidity	Much infectious disease, no epidemics	Epidemics, endemic disease (plague, smallpox, polio, tuberculosis), deficiency disease begins, starving common	Tuberculosis, smallpox infection, parasitic disease, polio, weaning disease (diarrhea, retarded growth) expand, later decline	Chronic disease related to diet and pollution (heart disease, cancer), decline in infectious disease	Increases in health promotion (preventive and therapeutic), rapid decline in cardiovascular disease, slower change in age-specific cancer profile
Age structure	Young population	Young, very few elderly	Chiefly young, shift to older population begins	Rapid decline in fertility, rapid increase in proportion of elderly person	Increases in the proportion of elderly >75 y of age
Residency patterns	Rural, low density	Rural, a few small, crowded cities	Chiefly rural, move to cities increases, international migration begins, megacities develop	Dispersal of urban population decrease in rural green space	Lower-density cities rejuvenate, increase in urbanization of rural areas encircling cities
Food processing	Nonexistent	Food storage begins	Storage processes (drying, salting) begin, canning and processing technologies emerge, increases in food refining and milling	Numerous food-transforming technologies	Technologies create foods and food constituent substitutes (eg, macronutrient substitutes)

[1] MCH, maternal and child health.

WHY THE CONCERN?

The shift from the receding famine pattern (pattern 3) to one dominated by nutrition-related NCDs has been very rapid in most low- and middle-income economies; moreover, there is evidence of a speeding up of this transition in higher-income, more economically developed economies (5). Weight and height data are

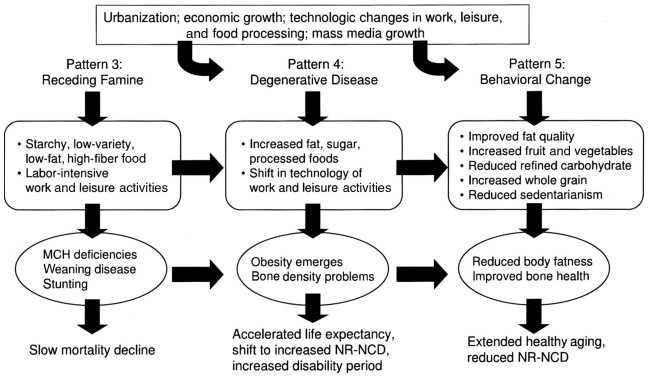

FIGURE 1. Patterns of the nutrition transition (2). NR-NCD, nutrition-related noncommunicable disease; MCH, maternal and child health.

the nationally representative noncommunicable and nutritional measures most available in both high- and low-income countries. These data provide some sense of the rate of change in obesity and of the rapidly changing faces of global obesity.

Obesity prevalence and trends

Nationally representative data are presented for a large number of countries in **Figure 2**A. Only data for Africans (blacks) are presented for South Africa; data from only 9 provinces are presented for China, but these data mirror closely national levels and trends. Essentially, overweight and obesity levels are consistently high in an array of high-income countries (but the levels are much lower in other European countries), and several lower-income countries (eg, Mexico, Egypt, and South Africa) have equally high levels of obesity among women. Other very large countries (eg, China) have obesity rates of >20% for women and men.

What is potentially far more important are the rates of change in the prevalence of overweight and obesity in these countries, as shown in Figure 2B. A large number of lower- and middle-income countries (eg, Mexico, Thailand, China, and Indonesia) are experiencing an annual increase (in percentage points) in overweight and obesity >1. Only in the United Kingdom and Australia are such rates seen in higher-income countries.

Are these rates of change accelerating?

We explored the relative rates of change across the world for adults and children in a new study and have long-term comparable data for Brazil and the United States (5). Earlier changes in these 2 countries refer mostly to the mid- 1970s, the 1980s, recent changes to the 1990s, and to the early 2000s. In Brazil, time trends indicate a deceleration in the combined overweight and obesity levels for adults; however, the increase in the combined overweight and obesity levels shows an acceleration for US adults. Studies in China show patterns similar to those in Brazil. The rate of change in the prevalence of overweight in

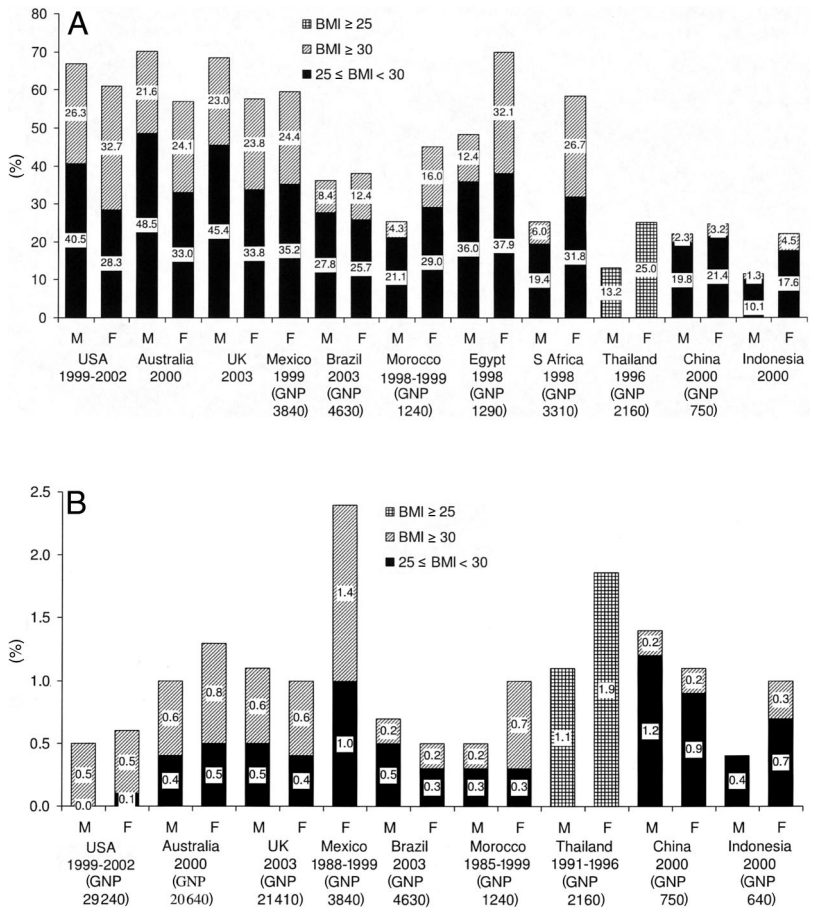

FIGURE 2. Obesity patterns throughout the world (A) and increases in obesity among adults (B) in selected countries (2). US, United States; UK, United Kingdom; GNP, gross national product (per capita US $); S, South.

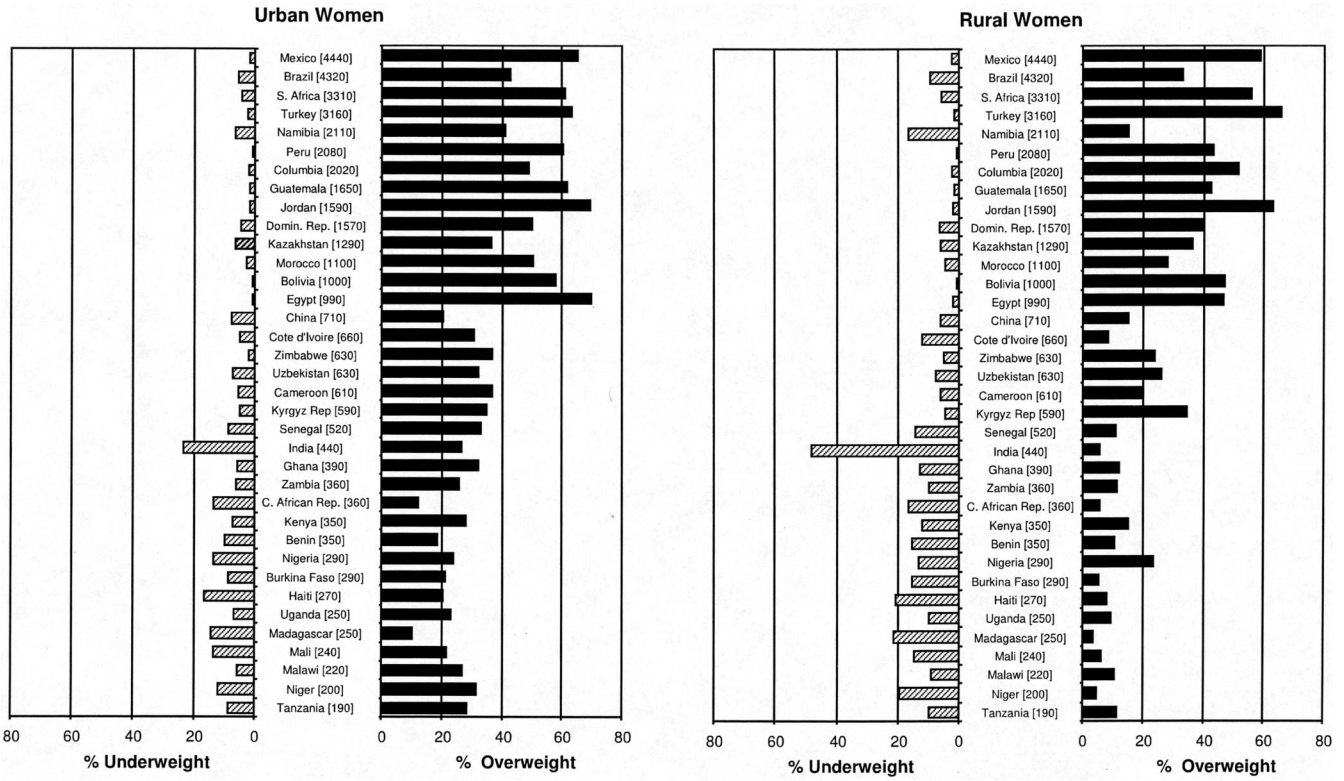

FIGURE 3. Prevalence of overweight [BMI (in kg/m^2) ≥ 25] and underweight (BMI < 18.5) in women aged 20-49 y in 36 developing countries ranked (in brackets) by per capita gross national income (US $). Reprinted with permission (9). Dom, Dominican; Rep, Republic; C, Central; S, South.

China accelerated from <0.5% in 1980–1990 to 1.9% and 0.9% in 1997–2000 for men and women, respectively (6); preliminary data for 2004 indicate that these changes are still accelerating. In the dietary area, we have documented longitudinally that income elasticity, or the proportion of food purchases with a 1% increase in income, has accelerated at an increasing rate in the past 15 y (7, 8).

Obesity is universally found in urban and rural areas

In an article published in this Journal, we provided nationally representative data for women aged 20–49 y (n = 148 579) from 1992 to 2000 in 36 countries (9). The article presents data on both underweight and overweight plus obesity status in low-income and transitional countries. The summary shown in **Figure 3** provides a clear picture of these differential patterns; overweight plus obesity exceeded underweight in most countries. Countries with high income and urbanization levels not only had high absolute levels of overweight plus obesity, but they also had small urban-rural differences in overweight and very high ratios of overweight plus obesity to underweight. In more-developed countries, overweight among women with a low socioeconomic status was high in both rural (38%) and urban (51%) settings. Even many poor countries—where underweight persists as a significant problem—had fairly high levels of overweight in rural area (9).

Adult obesity appears to precede child obesity

We recently explored this question using nationally representative data from 6 countries and nationwide representative data from a seventh country—all measured at least twice during the 1985–2004 period (5). This study used the single body mass index (kg/m^2) cutoff of 25 (overweight plus obesity), whereas the International Obesity Task Force sex- and age-specific body mass index cutoffs for children are equivalent to 25 at 18 y of age. It is not possible to compare prevalences between the standards used for children and adults; however, this analysis focuses on rates of change in these prevalences that can be compared.

Absolute rates of increase in overweight plus obesity tended to be higher among adults than among children in most countries—much higher in the 2 low-income countries (ie, China and Indonesia) and moderately higher in Brazil and in 2 of the 3 high-income countries (ie, the United Kingdom and the United States). The only country where overweight plus obesity increased more among children than adults was Australia. However, relative rates of increase in overweight indicate faster increases in overweight among children in Brazil and in the 3 high-income countries. As a result, the relative excess of overweight among adults, seen initially in all countries, increased in China, Indonesia, and Russia but decreased in Australia, Brazil, the United Kingdom, and the United States.

Although patterns indicate that there will be an increasing global obesity problem among children to match the adult problem, other equally disturbing data on adult-onset diabetes are emerging, not only from the United States but also globally. In the United States, many scholars are pointing to a large and important increase in adult-onset diabetes among adolescents—a phenomenon previously unseen (10–13). In the developing world, the mean and median ages for adult-onset diabetes have been lower than in the United States, which possibly points to similar global problems in the future (14, 15).

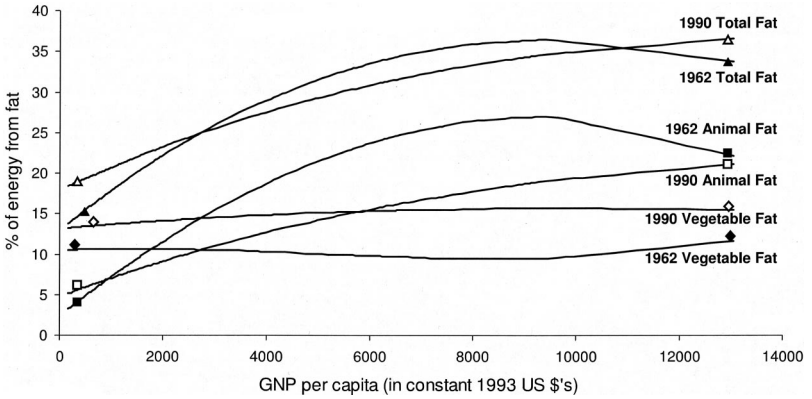

FIGURE 4. Relation between the percentage of energy intake from fat and the per capita gross national product (GNP) in 1962 and 1990. Reprinted with permission (8).

WHAT ARE THE KEY DIETARY DIMENSIONS?

Globally, our diet is becoming increasingly energy-dense and sweeter. At the same time, higher-fiber foods are being replaced by processed versions. There is enormous variability in eating patterns globally, but the broad themes seem to be retained in most countries.

Eating pattern shifts, in particular, seem to be specific to different regions and sets of countries (16). In the higher-income countries, increased portion sizes, away-from-home food intake, and snacking are eating pattern shifts that accompany these changes (17–20). Water and milk appear to be replaced by calorically sweetened beverages (18, 21). Dozens of studies document these shifts in the United States, but few studies document these same shifts in other higher-income countries, where concern for these shifts is greatest (22). Much less documentation exists for lower-income countries, and there seems to be more heterogeneity in terms of the shifts to away-from-home food intake (16). For instance, away-from-home food intake and snacking are as high in the Philippines as in the United States but is rare in Russia and China.

The global shifts in the energy density of the diet are equally difficult to document. One can document large increases in the consumption of edible oils and animal-source foods for selected countries (7, 23) with the help of well-collected, repeated 24-h recall measures of dietary intake. However, in general, most research has focused on the use of food disappearance data from the Food and Agricultural Organization. With these data, which are not as accurate in picking up smaller shifts in consumption and wastage (24), it is possible to see that the shifts in edible oil intake are universal. In one set of analyses that compared edible oil intake patterns in the 1960s with those in the 1990s based on food disappearance data, large increases in edible oil available for intake were shown particularly for lower income countries (8, 25). The crude picture of the increased intake of vegetable fats (edible oils) is being seen globally, as shown in **Figure 4**. However, average daily intakes in a country such as China, where we measured intakes with recall and direct measures of household consumption, were much higher. For example, individual adults in China with >30% of energy intake from fat increased from ≈15% to 44% between 1989 and 2000.

Animal-source food changes are equally dramatic, particularly in selected countries (26). In China, we documented very large increases in animal-source food intake (23, 27). Egg, poultry, beef, and pork consumption have increased rapidly in China, and milk intake has recently begun to rise. Today, the average Chinese adult consumes >1300 kcal/d of pork, poultry, beef, mutton, fish, eggs, and dairy foods. As we showed elsewhere, the structure of consumption shifts in China is such that for each additional increase in income, adults proportionally increase their intake of animal-source foods (7, 8, 27).

Concurrent shifts are occurring in the use of caloric sweeteners. Only a few countries have published studies of the trends concerning the specific foods in which caloric sweeteners are found; the United States and South Africa are 2 of these countries (18, 28–31). In the United States, calorically sweetened beverages (eg, soft drinks and fruit drinks) account for >50% of the increase in added caloric sweeteners in the past several decades; the foods responsible for caloric sweetener intake in South Africa are much more varied than in the United States (18, 28–31).

Elsewhere, we used food disappearance data to document the worldwide increase in caloric sweeteners to the diet. We showed that, as national income [gross national product (GNP)] per capita and the proportion of the population residing in urban areas increased, sugar intake also increased (28). This relation is shown in **Figure 5**, with countries grouped by GNP in 1962. The changes are larger for lower- and middle-income countries. Urbanization and national income per capita are correlated highly in the developing countries that have access to processed foods higher in sugar. Urbanization is also linked with greater access to modern mass media, to better transportation systems, and to larger, modern supermarkets dominated by multinational corporations (32, 33). Although increases in per capita income have occurred, in most cases, hand-in-hand with urbanization, per capita income plays a powerful separate role in food consumption decisions, particularly in relation to the consumption of more processed foods.

The studies on fiber intake and other changes toward processed foodstuffs are much more incomplete. Because the issue of reduced fiber intake in the Western diet was first discussed as a major health concern, there have been few systematic studies of shifts in fiber intake throughout the world. However, important historical case studies have documented these shifts for selected population groups and countries (34, 35). Specific shifts in diet

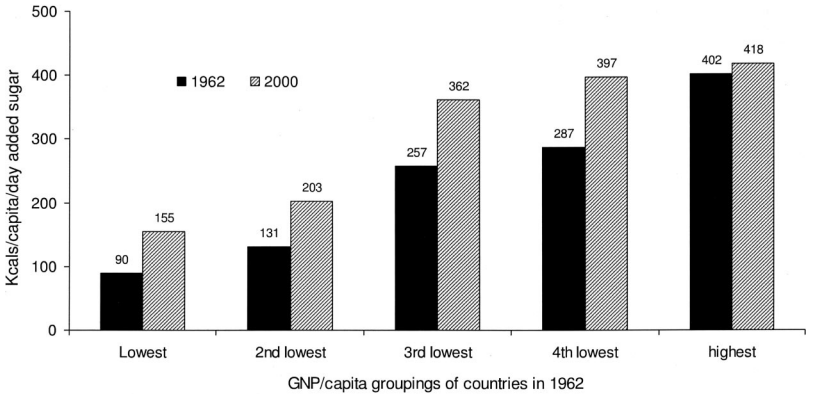

FIGURE 5. Relation between changes in the per capita gross national product (GNP; US $) and caloric sweetener intake. Reprinted with permission (28).

from coarse grains to refined grains in a few countries have also been documented (36).

Similarly, studies of fruit and vegetable intakes indicate decreased intakes in many countries and regions of the world, but, again, this trend has not been systematically studied (21, 25, 37). Fruit and vegetable intakes remain very high in selected countries, eg, Spain, Greece, and South Korea (38–40).

WHAT ARE THE KEY PHYSICAL ACTIVITY SHIFTS?

National or large-scale monitoring of overall physical activity patterns did not exist before the late 1990s, except in a few rare exceptions (41–43). In general, research on physical activity and its changes in the world has focused mainly on the role of leisure activities, particularly television viewing (44–46). In China, research has shown that shifts in the types of occupations, levels of activity at each occupation, and shifts in the mode of transportation (from active to more passive) are potentially very important (43, 47, 48). Limited research on shifts in more common day-to-day activities linked with home production and other forms of movement has been conducted by Levine et al (49, 50). This research suggests that major shifts in this area are linked with the use of more modern technologies in the workplace, in the shopping arena, and at home. The picture of overall shifts in activity, their causes, and their consequences are still incomplete. Typically, scholars examine changes in each element of physical activity. We are yet to see studies of joint shifts in all activity components to enable us to begin to understand *1*) what the past shifts have been, *2*) what potentially future shifts are the most important, and *3*) how to use this knowledge to guide policies on increasing activity in a more coherent manner.

WHAT ARE THE MAJOR UNDERLYING GLOBAL FORCES?

Globalization

Globalization, with its focus on freer movement of capital, technology, goods, and services, has had profound effects on lifestyles that are linked with diet, activity, and subsequent imbalances that have led to the obesity epidemic. Although many researchers have placed the global food production, marketing, and distribution sectors (including soft drink, fast food, and other multinational food companies) at the center of blame for these changes, there are other profound and equally responsible factors that must be understood to enact effective public policy to address them (51). These other factors include *1*) worldwide shifts in the trade of technology innovations that affect energy expenditures during leisure, transportation, and work; *2*) globalization of modern food processing, marketing, and distribution techniques (most frequently linked with westernization of the world's diet); *3*) vast expansion of the global mass media; and *4*) other changes that constitute the rubric of the effects resulting from an increased opening of our world economy (52, 53).

One of the central shifts has occurred in the global food system, which is related to the marketing and sales of food. The fresh (wet or open public) market is disappearing as the major source of supply for food in the developing world. These markets are being replaced in some countries by multinational, regional, and local large supermarkets—supermarkets that are usually part of larger chains (eg, Carrefour or Walmart)—or by local domestic chains patterned to function and look like these global chains in other countries, such as South African and China. Increasingly, we are finding hypermarkets (very large megastores) as the major force driving shifts in food expenditures in a country or region. For example, in Latin America, the supermarkets' share of all retail food sales increased from 15% in 1990 to 60% by 2000 (32). For comparison, 80% of retail food sales in the United States in 2000 occurred in supermarkets. In one decade, the role of supermarkets in Latin America has expanded by an amount equivalent to that which occurred over about a half century in the United States (54). Supermarket use has spread across both large and small countries, from capital cities to rural villages, and from upper- and middle-class families to the working class (55). This same process is also occurring at varying rates and different stages in Asia, Eastern Europe, and Africa.

Many factors are responsible for this food system phenomenon (56). Consumer demand for processed and safer foods is on the rise in developing countries. Additionally, as countries modernize, the opportunity cost of women's time has grown; building a market for time-saving, prepared foods has become more important. Transportation and access to technology (eg, refrigerators) has also played a role in the demand for, and access to, supermarkets. Other factors include the liberalization of direct foreign investment, trade liberalization, and the saturation of Western markets that has pushed growing companies into other

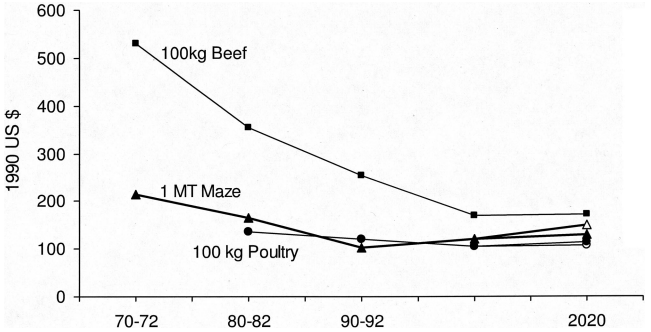

FIGURE 6. Real world prices in 1990 US $ over the years 1970–1972, 1980–1982, and 1990–1992 and projected estimates in 2020. Unpublished figure used with permission from Delgado et al (58). MT, metric tons.

locales. Furthermore, improvements in the logistics and procurement systems used by the supermarkets have allowed them to compete, on cost, with the more typical outlets in developing countries, ie, the small "mom-and-pop" stores and wet markets (fresh or open public markets) for fruit, vegetables, and all other products.

Supermarkets are large providers of processed higher-fat, added-sugar, and salt-laden foods in developing countries, but they have also been the purveyors of some good. For example, supermarkets were *1*) instrumental in the development of ultra-heat treatment, high-temperature pasteurized milk, which gives milk a long shelf life and provides a safe source of milk for all income groups, and *2*) were key players in establishing food safety standards (57). Most importantly, supermarkets have solved the problem of keeping animal-source products chilled and in many instances have brought higher-quality produce to the urban consumer throughout the year.

Global agricultural policies

Global agricultural policies have a built-in long-term focus on creating cheaper grains and animal-source foods. The relation between these policies and the shift in livestock and other animal-source food intakes is documented by Delgado et al (26, 58). One clear outcome has been a dramatic decline in the real price of beef and related products. The huge decline in the global cost of 100 kg beef to ≈20% of its initial costs over a 4-decade period is presented in **Figure 6**.

Global mass media

Global mass media access has shifted in an equally impressive manner. Minimal research has been conducted on how the increased global access has affected dietary and physical activity behavior, but it is clear from the extent of global food advertising growth that it is important. For instance, television viewership in China has more than tripled over a decade; ≈95% of all households had working television sets during the 1990s. Moreover, television programming has shifted from political and educational offerings prepared by the national or provincial governments to modern Chinese, Asian, and Western programming. For example, in the 9 provinces and 227 communities monitored by the China Health and Nutrition Survey, no Hong Kong Phoenix cable or satellite television was available until 1993; in 2004, 10% of these communities were watching these Western programmed channels, and viewing is expected to accelerate greatly. At the same time, advertising content has shifted to more modern marketing. The effects of such changes in television programming are found throughout the developing world. The effect of such shifts in television access and programming are not understood.

Television and other media penetration has been complete for several decades in Europe, the United States, and other higher-income countries, which has made it difficult for studies to unravel the exact causal effects of television viewing on nutrition-related behaviors (44).

DO COCA-COLA AND MCDONALD'S HAVE ANY RESPONSIBILITY?

Some researchers believe that the fast food sector and soft drink industry in the United States have led to the decline in the quality of diets throughout the developing world (51, 59). The growth of American food companies has certainly spread across the globe. Coca-Cola products are sold in >200 countries, and >50% of McDonald's sales are made outside the United States. Many other examples can be found to show that the numbers of McDonald's, Pizza Hut, and Kentucky Fried Chicken restaurants are growing rapidly across the globe. Most interesting is the number of local restaurants and chains that have attempted to copy these American fast food models—even to the point of serving the same dishes and being equally hygienic and efficient (60).

Much research has been conducted on the effect of fast food restaurant patronization on current dietary patterns in the United States, but little research has been conducted in the rest of the world (19, 20, 61, 62). One 4-country comparison of fast food intakes and other elements of modern food intake was undertaken for China, the Philippines, Russia, and the United States by using comparable 24-h recall data (63). This study examined away-from-home food intake overall and fast food and soft drink intakes among children and adolescents. The results indicate very low levels of away-from-home food intake in Russia and China, but equally high intakes in the Philippines and the United States. Intake of fast foods and soft drinks in the Philippines was less than one-fifth that in the United States and was miniscule in China and Russia (63).

THE ECONOMIC COSTS OF THIS TRANSITION ARE HUGE

In the United States and other higher-income countries, several analyses of the health costs and other effects of this shift toward higher obesity have been conducted. For instance, Wolfe and Colditz (64, 65) have undertaken several studies of this topic using a cost-accounting perspective. Finklestein et al (66–68) followed a more behavioral approach and examined how obesity affects medical expenditures.

In developing countries, far less has been done to study this issue. In one set of studies on the economic costs in India and China, it was shown that these costs are rapidly increasing and represent a serious component of their GNP (37, 69). In fact, it is possible that these economic effects of the shift toward the degenerative disease stage of the nutrition transition will overwhelm the health system of China and slow its economic growth (70).

DO WE HAVE ANY POSITIVE MODELS AT THE NATIONAL OR REGIONAL LEVEL?

Few countries or regions have made significant program and policy changes that have resulted in positive shifts in dietary patterns and in considerable decreases in nutrition-related NCDs. Finland is one example that pointedly shows how intersectoral collaboration with one responsible national agency as the focal point can be very effective (71). In Finland, national price policy and food-labeling policies were combined with nutrition education programs and the enlistment of voluntary organizations to tackle this effort (72, 73).

Brazil is the only country with limited evidence of a decrease in obesity in one region (74, 75). This decrease in obesity preceded a series of major initiatives in Brazil to further the decrease in obesity among women with a high socioeconomic status and to possibly slow the decline in other populations (76–78). Brazil's initiative to improve dietary patterns began as a coordinated and systematic initiative that included many important legislative and regulatory policies and changes to the national school feeding program (76). This effort appears to have slowed considerably under the new president.

South Korea has long promoted the consumption of a traditional diet—ie, one rich in vegetables and low in fat—in lieu of the type of dietary shifts found in other middle-income countries (39, 40). For many decades the government has advised against modern Western cuisine and has provided intensive training to newly married women about the preparation of traditional dishes. The results of these efforts have been lower obesity levels and lower intakes of energy from fat than would be expected given the high income level of this country and much higher intakes of vegetables than observed in other Asian countries (39, 40).

DISCUSSION

This commentary on the global shifts in the patterns of the nutrition transition addresses a broad range of socioeconomic and demographic shifts that have resulted in rapid changes in the diets and physical activity levels of most regions of the world. The available data seem to indicate that most of the changes have involved reductions in fiber and whole grain intakes, increases in refined carbohydrate intakes (particularly in sweeteners), and increases in intakes of animal and partially hydrogenated fats. The shifts in activity patterns appear to have been equally rapid but are more poorly documented.

Although nutritionists and other health professionals might view these diet changes—specifically the shifts toward higher intakes of animal and partially hydrogenated fats and lower intakes of fiber—to be negative, there has also been a shift toward a more diverse and pleasurable diet. The activity patterns also represent a shift away from onerous, difficult, labor-intensive activities. Thus, although these shifts in diet and physical activities are desirable in many ways, they are associated with many onerous nutritional and health effects. It is this paradox and complexity that make it difficult to arrest the negative aspects of the nutrition transition. Since the development of the wheel and fire, humankind has attempted to reduce the effort involved with activities both at home and away from the home. Our striving to increase the tastefulness of the diet has been equally important. Fat and sugar are 2 of the more pleasurable elements of the diet in terms of taste preferences.

Obesity results from the interaction of genetic susceptibility factors and modifiable environmental factors, with genetic variations influencing a person's susceptibility to environmental factors. We still have a remarkably weak global database for truly understanding these changes. Few countries put energy into monitoring or studying these dynamics at the national or regional level. Extensive documentation on micronutrient deficiencies and protein-energy malnutrition is available; however, remarkably little data exists about large-scale dietary and physical activity patterns, despite evidence that there are more overweight or obese than underweight or malnourished persons in the world; this disparity is growing rapidly.

Our challenge is to devise ways to improve the lives of our citizens, ie, to *1*) provide more varied and tasteful diets; *2*) provide less burdensome work; *3*) prevent obesity, type 2 diabetes, and other aspects of the metabolic syndrome; and *4*) prevent a vast array of cancers linked with unhealthful dietary and activity patterns. However, the data indicate that few countries have tackled these issues at the national level. Milio (72, 73) studied these issues systematically and showed that little effort has been undertaken globally, nationally, or regionally to address them. Lower-income countries are only beginning to discuss and consider options for dealing with obesity. Concerns for poverty and hunger dominate the attention of the public and politicians, and it is difficult to get foundations and governments to focus on NCDs. We must also realize that these problems coexist in many countries and our solutions must not adversely affect the undernourished (79–81). At the same time, we must begin to develop an array of large-scale options that national governments can implement to address these issues (82). As with any other epidemic, we must focus much of our energy on environmental solutions.

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REFERENCES

1. Popkin B. Nutritional patterns and transitions. Popul Dev Rev 1993;19:138–57.
2. Popkin BM. An overview on the nutrition transition and its health implications: the Bellagio meeting. Public Health Nutr 2002;5:93–103.
3. Manton KG, Soldo BJ. Dynamics of health changes in the oldest old: new perspectives and evidence. Milbank Mem Fund Q Health Soc 1985;63:206–85.
4. Crimmins EM, Saito Y, Ingegneri D. Changes in life expectancy and disability-free life expectancy in the United States. Popul Dev Rev 1989;15:235–67.
5. Popkin BM, Conde W, Hou N, Monteiro C. Why the lag globally in obesity trends for children as compared to adults? Obesity (in press).
6. Wang H, Du S, Zhai F, Popkin BM. Trends in the distribution of body mass index among Chinese adults, aged 20–45 years (1989 to 2000). In t J Obes Relat Metab Disord (in press).
7. 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;59:1505–15.
8. Guo X, Mroz TA, Popkin BM, Zhai F. Structural changes in the impact of income on food consumption in China, 1989–93. Econ Dev Cultural Change 2000;48:737–60.
9. Mendez MA, Monteiro, Carlos A, Popkin BM. Overweight exceeds underweight among women in most developing countries. Am J Clin Nutr 2005;81:714–21.
10. Lipton RB, Drum M, Burnet D, et al. Obesity at the onset of diabetes in an ethnically diverse population of children: what does it mean for epidemiologists and clinicians? Pediatrics 2005;115:e553–60.
11. Saaddine JB, Fagot-Campagna A, Rolka D, et al. Distribution of

HbA(1c) levels for children and young adults in the U.S.: Third National Health and Nutrition Examination Survey. Diabetes Care 2002;25:1326–30.
12. Clinton Smith J. The current epidemic of childhood obesity and its implications for future coronary heart disease. Pediatr Clin North Am 2004;51:1679–95, x.
13. Hale DE. Type 2 diabetes and diabetes risk factors in children and adolescents. Clin Cornerstone 2004;6:17–30.
14. Zimmet PZ, McCarty DJ, de Courten MP. The global epidemiology of non-insulin-dependent diabetes mellitus and the metabolic syndrome. J Diabetes Complications 1997;11:60–8.
15. King H, Aubert RE, Herman WH. Global burden of diabetes, 1995–2025: prevalence, numerical estimates, and projections. Diabetes Care 1998;21:1414–31.
16. Adair LS, Popkin BM. Are child eating patterns being transformed globally? Obes Res 2005;13:1281–99.
17. Jahns L, Siega-Riz AM, Popkin BM. The increasing prevalence of snacking among US children from 1977 to 1996. J Pediatr 2001;138:493–8.
18. Nielsen SJ, Popkin BM. Changes in beverage intake between 1977 and 2001. Am J Prev Med 2004;27:205–10.
19. Nielsen SJ, Popkin BM. Patterns and trends in food portion sizes, 1977–1998. JAMA 2003;289:450–3.
20. Nielsen SJ, Siega-Riz AM, Popkin BM. Trends in food locations and sources among adolescents and young adults. Prev Med 2002;35:107–13.
21. Cavadini C, Siega-Riz AM, Popkin BM. US adolescent food intake trends from 1965 to 1996. West J Med 2000;173:378–83.
22. Cummins SC, McKay L, Macintyre S. McDonald's restaurants and neighborhood deprivation in Scotland and England. Am J Prev Med 2005;29:308–10.
23. Du S, Lu B, Zhai F, Popkin BM. A new stage of the nutrition transition in China. Public Health Nutr 2002;5:169–74.
24. Crane NT, Lewis CJ, Yetley EA. Do time trends in food supply levels of macronutrients reflect survey estimates of macronutrient intake? Am J Public Health 1992;82:862–6.
25. Drewnowski A, Popkin BM. The nutrition transition: new trends in the global diet. Nutr Rev 1997;55:31–43.
26. Delgado CL. Rising consumption of meat and milk in developing countries has created a new food revolution. J Nutr 2003;133(suppl):3907S–10S.
27. 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(suppl):3898S–906S.
28. Popkin BM, Nielsen SJ. The sweetening of the world's diet. Obes Res 2003;11:1325–32.
29. 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;79:537–43.
30. Steyn NP, Nel JH, Casey A. Secondary data analyses of dietary surveys undertaken in South Africa to determine usual food consumption of the population. Public Health Nutr 2003;6:631–44.
31. Steyn NP, Myburgh NG, Nel JH. Evidence to support a food-based dietary guideline on sugar consumption in South Africa. Bull World Health Organ 2003;81:599–608.
32. Reardon T, Berdegué JA. The rapid rise of supermarkets in Latin America: challenges and opportunities for development. Dev Policy Rev 2002;20:371–88.
33. Reardon T, Timmer P, Berdegue J. The rapid rise of supermarkets in developing countries: induced organizational, institutional, and technological change in agrifood systems. J Agric Dev Econ 2004;1:168–83.
34. Trowell HC, Burkett DP, eds. Western diseases: their emergence and prevention. Cambridge, MA: Harvard University Press, 1981.
35. Hughes RE, Jones E. A Welsh diet for Britain? BMJ 1979;1:1145.
36. Popkin BM, Keyou G, Zhai F, Guo X, Ma H, Zohoori N. The nutrition transition in China: a cross-sectional analysis. Eur J Clin Nutr 1993;47:333–46.
37. Popkin B, Horton S, Kim S. The nutrition transition and prevention of diet-related chronic diseases in Asia and the Pacific. Food Nutr Bull 2001;22:1–58.
38. Moreno LA, Sarria A, Popkin BM. The nutrition transition in Spain: a European Mediterranean country. Eur J Clin Nutr 2002;56:992–1003.
39. Lee MJ, Popkin BM, Kim S. The unique aspects of the nutrition transition in South Korea: the retention of healthful elements in their traditional diet. Public Health Nutr 2002;5:197–203.
40. Kim S, Moon S, Popkin BM. The nutrition transition in South Korea. Am J Clin Nutr 2000;71:44–53.
41. Tudor-Locke C, Ainsworth BE, Adair LS, Du S, Popkin BM. Physical activity and inactivity in Chinese school-aged youth: the China Health and Nutrition Survey. Int J Obes Relat Metab Disord 2003;27:1093–9.
42. Tudor-Locke C, Neff LJ, Ainsworth BE, Addy CL, Popkin BM. Omission of active commuting to school and the prevalence of children's health-related physical activity levels: the Russian Longitudinal Monitoring Study. Child Care Health Dev 2002;28:507–12.
43. Bell AC, Ge K, Popkin BM. Weight gain and its predictors in Chinese adults. Int J Obes Relat Metab Disord 2001;25:1079–86.
44. Committee on Food Marketing and the Diets of Children and Youth. Food marketing to children and youth: threat or opportunity? Washington, DC: National Academy Press, 2005.
45. Dietz WH, Gortmaker SL. Preventing obesity in children and adolescents. Annu Rev Public Health 2001;22:337–53.
46. Gortmaker SL, Must A, Sobol AM, Peterson K, Colditz GA, Dietz WH. Television viewing as a cause of increasing obesity among children in the United States, 1986–1990. Arch Pediatr Adolesc Med 1996;150:356–62.
47. Bell AC, Ge K, Popkin BM. The road to obesity or the path to prevention: motorized transportation and obesity in China. Obes Res 2002;10:277–83.
48. Paeratakul S, Popkin BM, Keyou G, Adair LS, Stevens J. Changes in diet and physical activity affect the body mass index of Chinese adults. Int J Obes Relat Metab Disord 1998;22:424–31.
49. Levine JA, Lanningham-Foster LM, McCrady SK, et al. Interindividual variation in posture allocation: possible role in human obesity. Science 2005;307:584–6.
50. Lanningham-Foster L, Nysse LJ, Levine JA. Labor saved, calories lost: the energetic impact of domestic labor-saving devices. Obes Res 2003;11:1178–81.
51. Brownell K, Horgan, K. Food fight: The inside story of the food industry, America's obesity crisis, and what we can do about it. New York, NY: Contemporary Books, 2004.
52. Mendez MA, Popkin B. Globalization, urbanization and nutritional change in the developing world. J Agric Dev Econ [serial online] 2005;1:220–41.
53. Popkin BM. Technology, transport, globalization and the nutrition transition. Food Policy (in press).
54. Reardon T, Timmer CP, Barrett CB, Berdegue JA. The rise of supermarkets in Africa, Asia, and Latin America. Am J Agric Econ 2003;85:1140–6.
55. Hu D, Reardon T, Rozelle S, Timmer P, Wang H. The emergence of supermarkets with Chinese characteristics: challenges and opportunities for China's agricultural development. Dev Policy Rev 2004;22:557–86.
56. Wilkinson J. The food processing industry, globalization and developing countries. J Agric Dev Econ [serial online] 2004;1:184–201.
57. Balsevich F, Berdegue JA, Flores L, Mainville D, Reardon T. Supermarkets and produce quality and safety standards in Latin America. Am J Agric Econ 2003;85:1147–54.
58. Delgado CL, Rosegrant M, Steinfield H, Ehui S, Courbois C. Livestock to 2020: the next food revolution. Washington, DC: International Food Policy Research Institute, 1999.
59. Lobstein T, Baur L, Uauy R. Obesity in children and young people: a crisis in public health. Obes Rev 2004;5:4–97.
60. Watson J. Golden arches east: McDonald's in East Asia. Stanford, CA: Stanford University Press, 1997.
61. French SA, Story M, Neumark-Sztainer D, Fulkerson JA, Hannan P. Fast food restaurant use among adolescents: associations with nutrient intake, food choices and behavioral and psychosocial variables. Int J Obes Relat Metab Disord 2001;25:1823–33.
62. Jeffery RW, French SA. Epidemic obesity in the United States: are fast foods and television viewing contributing? Am J Public Health 1998;88:277–80.
63. Popkin B, Adair L. Are child eating patterns being transformed globally? Obes Res 2005;13:1281–99.
64. Wolf AM, Colditz G. Current estimates of the economic costs of obesity in the United States. Obes Res 1998;6:97–106.
65. Wolf AM, Colditz GA. Social and economic effects of body weight in the United States. Am J Clin Nutr 1996;63(suppl):466S–9S.

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66. Finkelstein EA, Fiebelkorn IC, Wang G. National medical spending attributable to overweight and obesity: how much, and who's paying? Health Aff (Millwood) 2003;Suppl Web Exclusives:W3–219-26.
67. Finkelstein EA, Fiebelkorn IC, Wang G. State-level estimates of annual medical expenditures attributable to obesity. Obes Res 2004;12:18–24.
68. Finkelstein EA, Ruhm CJ, Kosa KM. Economic causes and consequences of obesity. Annu Rev Public Health 2005;26:239–57.
69. Popkin BM, Horton S, Kim S, Mahal A, Shuigao J. Trends in diet, nutritional status, and diet-related noncommunicable diseases in China and India: the economic costs of the nutrition transition. Nutr Rev 2001; 59:379–90.
70. Popkin B, Kim S, Rusev E, Du S, Zizza C. Measuring the full economic costs of diet, physical activity, and obesity-related chronic diseases. Obes Rev (in press).
71. Puska P, Pirjo P, Uusitalo U. Influencing public nutrition for noncommunicable disease prevention: from community intervention to national programme- experiences from Finland. Public Health Nutr 2002; 5:245–51.
72. Milio N. Making healthy public policy: developing the science by learning the art: an ecologic framework for policy studies. Health Promot 1988;2:263–74.
73. Milio N. Nutrition policy for food-rich countries: a strategic analysis. Baltimore, MD: The Johns Hopkins University Press, 1990.
74. Monteiro CA, D'A Benicio MH, Conde WL, Popkin BM. Shifting obesity trends in Brazil. Eur J Clin Nutr 2000;54:342–6.
75. Monteiro CA, Conde WL, Popkin BM. Is obesity replacing or adding to undernutrition? Evidence from different social classes in Brazil. Public Health Nutr 2002;5:105–12.
76. Coitinho D, Monteiro CA, Popkin BM. What Brazil is doing to promote healthy diets and active lifestyles. Public Health Nutr 2002;5:263–7.
77. Matsudo V, Matsudo S, Andrade D, et al. Promotion of physical activity in a developing country: the Agita Sao Paulo experience. Public Health Nutr 2002;5:253–61.
78. Matsudo V. The "Agita Sao Paulo" experience in promoting physical activity. West Indian Med J 2002;51(suppl):48–50.
79. Doak CM, Adair LS, Bentley M, Monteiro C, Popkin BM. The dual burden household and the nutrition transition paradox. Int J Obes Relat Metab Disord 2005;29:129–36.
80. Doak C, Adair L, Bentley M, Fengying Z, Popkin B. The underweight/overweight household: an exploration of household sociodemographic and dietary factors in China. Public Health Nutr 2002;5:215–21.
81. Garrett JL, Ruel MT. Stunted child-overweight mother pairs: prevalence and association with economic development and urbanization. Food Nutr Bull 2005;26:209–21.
82. Haddad L. What can food policy do to redirect the diet transition? Food Nutr Bull 2005;26:238–40.