Original Article

Section 2

Nutrition in transition: The changing global nutrition challenge

Barry M Popkin PhD

Department of Nutrition, University of North Carolina at Chapel Hill, Chapel Hill, North Carolina, USA

The rapid shift in the stage of nutrition towards a pattern of degenerative disease is accelerating in the developing world. Data from China, as shown by the China Health and Nutrition Survey, between 1989 and 1993, are illustrative of these shifts. For example, an increase from 22.8 to 66.6% in the proportion of adults consuming a higher-fat diet, rapid shifts in the structure of diet as income changes, and important price relationships are examples that are presented. There appears to reflect a basic shift in eating preferences, induced mainly by shifts in income, prices and food availability, but also by the modern food industry and the mass media. Furthermore, the remarkable shift in the occupations structure in lower-income countries from agricultural labour towards employment in manufacturing and services implies a reduction in energy expenditure. One consequence of the nutrition transition has been a decline in undernutrition accompanied by a rapid increase in obesity. There are marked differences between urban and rural eating patterns, particularly regarding the consumption of food prepared away from home. Other issues considered are the fetal origins hypothesis, whereby the metabolic efficiencies that served well in conditions of fetal undernutrition become maladaptive with overnutrition, leading to the development of abnormal lipid profiles, altered glucose and insulin metabolism and obesity. Furthermore, obesity and activity are closely linked with adult-onset diabetes. The shift towards a diet higher in fat and meat and lower in carbohydrates and fibre, together with the shift towards less onerous physical activity, carries unwanted nutritional and health effects. It is also clear that the causes of obesity must be viewed as environmental rather than personal or genetic.

Key words: dietary trends, nutrition transition, obesity.

Introduction

Scientists have long recognized the importance of demographic and epidemiological transitions in higher-income countries and have more recently understood that similar sets of broadly based changes are occurring in lower-income countries. What has not been recognized is that concurrent changes are occurring in nutrition. Dietary intake patterns are changing rapidly, as are patterns of undernutrition and obesity. Elsewhere, we have provided a heuristic framework for this nutrition transition and have examined the dynamic nature of changes in diet and body composition in low-income countries.[1–4] The concept of nutrition transition used here focuses on the two dimensions of large shifts in diet, namely structure and overall composition, as well as on body size and body composition. By 'transitional societies', we refer to those previously low-income societies that are now facing significant improvements in income with concomitant changes in disease and dietary patterns. China and the countries of south-east Asia and the Middle East certainly fit this profile. In addition, most Latin American countries and many Caribbean and North African societies can be termed transitional.

Human diet and nutritional status have undergone a sequence of major shifts between each characteristic phase, defined as broad patterns of food use and corresponding nutrition-related disease. Over the past three centuries, the pace of dietary change appears to have accelerated, to varying degrees, in different regions of the world. The present article lays out an overview of patterns of change in the diets of low-income countries. It uses data from nationwide surveys in several countries that have experienced rapid economic change to present a brief case study of an emerging issue of international importance, namely the rapid shift in the structure of diet in low-income countries and the coexisting problems of undernutrition and overnutrition.

The article explores several themes that relate to: (i) a broad overview of the dynamic shifts in diets that include large increases in the consumption of dietary vegetable fat when countries and individuals living in countries felt to be low fat consumers have the resources that allow them to be able to afford dietary fat; (ii) information that shows that plant-based diets are not necessarily preferred as people have more income or as food supplies have expanded in response to consumer demand; (iii) information that shows that there is a marked increase in dietary diversity concurrent with income increases and that the plant-based simple peasant diet is not as attractive as heretofore assumed; and (iv) research that points towards some type of innate desire for fat.

Correspondence address: Dr BM Popkin, University of North Carolina at Chapel Hill, University Square, CB#8120, 123 W Franklin Street, Chapel Hill, NC 27516-3997, USA.
Tel.: 1 919 966 1732; Fax: 1 919 966 9159
Email: Popkin@unc.edu

Methods

The nutrition transition research programme uses large nationally representative surveys and nationwide surveys. Data collection in China followed informed consent procedures established by the Institutional Review Board of the University of North Carolina, Chapel Hill (UNC-CH) and the Institutional Review Boards of the Chinese Academy of Preventive Medicine. Families were informed about the study, its costs and its benefits and were asked to cooperate. The collection of dietary data occurred over a 3 day period. Each morning and evening, all food in the household was measured and weighed and each individual was interviewed to allow us to measure individual intake with great precision. Moreover, each of these datasets contains measures of income or expenditures for the household, which provide a basis for controlling for economic status. Elsewhere, we present in much more detail the design and methods used in this survey.[5,6]

The China Health and Nutrition Survey (CHNS) is an ongoing longitudinal survey that covers eight provinces in China: Guangxi, Guizhou, Henan, Hubei, Hunan, Jiangsu, Liaoning and Shangdong. Although this survey is not nationally representative, these provinces were selected to provide significant variability in geography, economic development and health indicators such that they may be considered to be generally representative of all provinces in the country. A multi-stage random cluster sampling procedure was used to draw the sample from each province. Data were collected from all household members. Trained teams measured weight using calibrated portable spring scales, with the individuals wearing lightweight clothing and no shoes. Data from the CHNS 1989, 1991 and 1993 are used in this article. Additional detail on the research design of this survey is presented elsewhere.[7]

Food balance data, from the Food and Agriculture Organization of the United Nations (FAO), are used here to present international comparisons on dietary patterns. Food balance data provide information about a country's average per capita dietary energy supply, which indicates the amount of food available for human consumption in the country. This is a measure of food production, taking account of imports minus exports, losses for animal feed, wastage and milling extraction rates. It ignores food lost at the retail and household level and is an approximation of average intake. In general, this is approximately 10–14% above actual food available for intake at the household level, but the overall structure of diet is remarkably similar to that seen with food balance data.

The statistical analysis of the food balance data for the period 1962–1990 is based on combining data on food availability, expressed in percentage of daily energy from macronutrients, with the official estimates of gross national product (GNP), as established by the World Bank.[8,9] Total national income (estimated from GNP) is divided by average household size to create a measure for per capita national income. Regression analyses were used to relate dietary data (the proportion of energy from vegetable and animal fats, carbohydrates, caloric sweeteners and protein) for those countries for which full sets of data were available in 1962 and in 1990 to the logarithm of per capita GNP. In both cases, GNP per capita was expressed in 1993 US dollars to allow for an easier comparison of the results. This research used all countries for which both sets of data were available. These numbered 98 in 1962 and 133 in 1990. When a similar analysis was made using alternative samples that consisted of countries with full sets of data in both 1962 and 1990, the results were identical.

Results and Discussion

Nutrition transition in China

Dramatic shifts in food consumption and physical activity patterns are occurring in most east and south-east Asian countries. China, with the world's fastest growing economy, is still in the relatively early stages of nutrition transition. As demonstrated below, countries with emerging economies, such as China, experience nutrition transition much sooner and at a much lower level of GNP than may have been expected from the earlier experience of the US and western European societies.

Dietary change in China has been extremely rapid. Over the past decade, China has attained a high measure of food security and has seen marked changes in the adequacy and structure of the diet.[5] What is most remarkable is that the traditional Chinese low-fat diet now appears to be possibly more a reflection of poverty rather than of a concern for good nutrition and health. The data in Fig. 1 present information on the proportion of adults who consume higher-fat diets. The classic Chinese low-fat diet appears to have been lost in the eating pattern shift that has accompanied the economic revolution in China. Upper-income respondents were more likely to consume a diet deriving more than 30% of energy from fat. By 1993, higher-income urban populations were far more likely to consume a diet deriving greater than 30% of energy from fat than were rural and lower-income households. The proportion of upper-income respondents who were consuming a relatively high-fat diet rose from 22.8 to 66.6% between 1989 and 1993. It is important to add that a minuscule proportion of the Chinese diet comes from imported foods and also from food consumed away from home. These changes appear to be basic shifts in eating preferences induced mainly by shifts in income, prices and food availability rather than by the modern food industry and the mass media.

At the same time, on the activity side, there has also been a rapid shift in Asia towards much more of a service sector

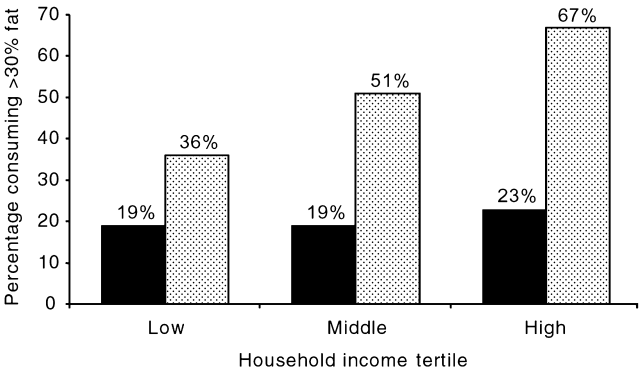

Figure 1. Proportions of Chinese adults in urban areas aged 20–45 years obtaining greater than 30% of energy from fat, by household income in 1989 (■) and 1993 (▨). Data from Popkin.[2]

economy and towards greater use of new technologies in current occupations. One of the most inexorable shifts with modernization and industrialization is the reduced use of human energy to produce more capital-intensive manufacturing and goods and services. The result is obviously a marked shift in activity patterns at work, a trend particularly associated with the shift into increasingly capital-intensive production and increasingly sedentary manufacturing, service and commercial work. This within-occupation shift in energy expenditure cannot be readily shown with national data. It requires individual level information. Unfortunately, few longitudinal studies attempt to measure physical activity and energy expenditures. One quite simple measure of overall activity has been collected in each survey from 16 000 Chinese as part of the CHNS. Figure 2 presents shifts in the proportion of urban Chinese adults involved in low levels of physical activity at work. Elsewhere, we have linked this with significant increases in body mass index (BMI) and obesity.[10]

The sectoral distribution of the labour force towards industry and services has accelerated around the world. Figure 3 presents data on this pattern for lower-income countries. It shows for all lower-income countries a pronounced movement away from agriculture towards employment in manufacturing and services. As has been shown often, the most labour-intensive agricultural work also requires the greatest amount of energy expenditure.

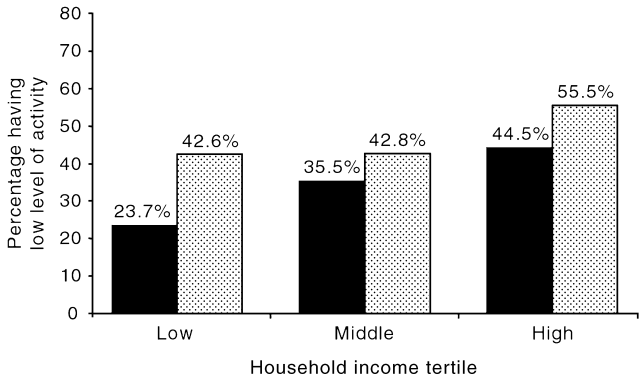

Figure 2. Activity levels of urban Chinese adults aged 20–45 years at their occupations in 1989 (■) and 1993 (▨). Data from the China Health and Nutrition Survey.

Obesity increases

One consequence of nutrition transition has been a decline in undernutrition accompanied by a rapid increase in obesity. In all age groups, there is evidence of a rapid increase in obesity and also an array of dietary excess and body composition-related health outcomes, such as glucose intolerance and diabetes. Monteiro *et al.*[11,12] have documented this shift away from undernutrition most clearly for Brazil. In Asia, obesity was an unknown condition 15 years ago among the lower-income and transitional economies. This is no longer the case. Figure 4 presents patterns of obesity among Asian adults.

In other unpublished research, we have found that the prevalence of overweight is emerging at a time when undernutrition, measured by low BMI, also continues to be a problem among children and adults (BM Popkin *et al.*, unpubl. data, 1999). Research by Doak *et al.*[13] shows that an important proportion of households in Brazil, China and the Russian Federation contain both overweight and underweight individuals. The prevalence of households with coexisting overweight and underweight members observed in those countries may be explained by dramatic changes in diet and physical activity associated with the stage of nutrition transition for each country. The proportion of underweight/overweight households in the three countries is consistent with the nutrition transition: the proportion is highest in Brazil (11%), which is undergoing rapid transition, and lowest in the Russian Federation (6.4%), which had already experienced the full transition. In 1993, China was in the early transition stages and, therefore, was experiencing more transition than the Russian Federation, but less than Brazil. The proportion of underweight/overweight households in the China survey was 8.7%, intermediate between Brazil and the Russian Federation. In addition, this research shows that 23–57% of households with an undernourished member also have an overweight person.

Rapid changes in diets and activity patterns

Rapid shifts in incomes, educational levels, proportions of individuals residing in an urban area and reduced cost of major sources of energy density are some of the explanations for the rapid shifts in dietary intake. Technological shifts are also very important for the shifts in activity patterns. Elsewhere, we have explored some of these factors in more depth.[4,7,14]

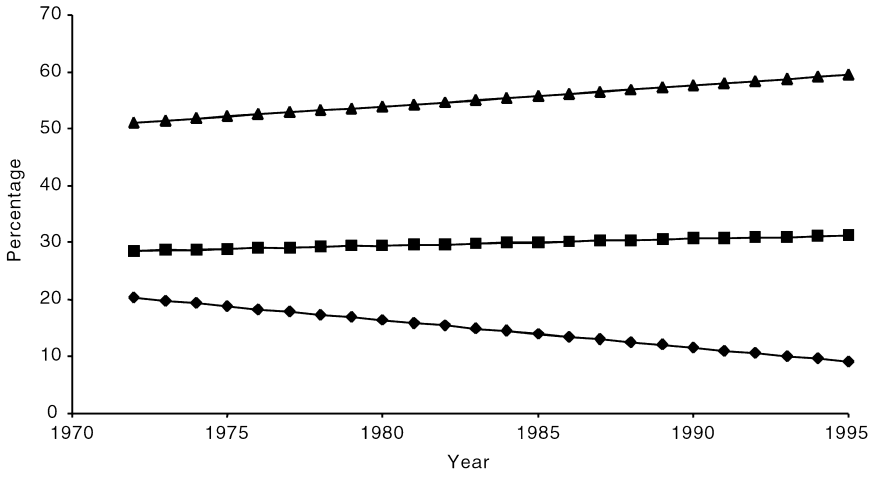

Figure 3. Shifts in the distribution of occupations for lower-income countries from 1972 to 1993. (▲), service industry; (■), manufacturing; (◆), agriculture. Data from Popkin and Doak.[25]

The evidence appears to point to a most pronounced association between urbanization with the shifts in diet, activity and body composition. People living in urban areas consume diets that are distinctly different from those of their rural counterparts. City dwellers have led the movement from the pattern of famine to the pattern of receding famine and the rise of degenerative disease. Compared with rural diets, urban diets show trends towards consumption of superior grains (e.g. rice or wheat, rather than corn or millet), more milled and polished grains (e.g. rice, wheat), food higher in fat, more animal products, more sugar and more food either prepared away from the home or processed.

The potential impact of urbanization on diet structure is shown by our regression model. The model was developed using FAO food balance sheets[8] and World Bank economic indicators data for 1990.[9] The regression relating GNP per capita to the outcomes of energy from each food source includes as a covariate the proportion of residents residing in urban areas and an interaction between the urban proportion and GNP per capita. For purposes of clarification of the impact of shifts in urbanization, the results of those regressions were used to predict (simulate) the diet structure with the proportion of urban residents worldwide at either 25 or 75%. As shown in Figs 5 and 6 for higher rates of urbanization, the simulation developed from our model predicts a substantial increase in the consumption of sweeteners and fats. The clear implication is that a shift from 25 to 75% urban population in very low-income countries would be associated with an added 4% total energy from fat and an additional 12% energy from sweeteners.[15]

When analysis is undertaken at the country level, it is clear that these contrasts between urban and rural eating patterns are more marked in lower- than higher-income countries. In higher-income countries, market penetration into rural areas is common and national integrated food distribution systems exist. Nevertheless, higher-income countries show important urban–rural differences in eating patterns, especially in the consumption of food prepared away from home and responsiveness to information and the influences of mass media. Even in higher-income countries, large differences between urban and suburban food and labour markets, in combination with other factors related to residence, result in distinct dietary and nutritional status patterns.

Key factors responsible for urban–rural differences in dietary intake and resulting differences in nutritional status include better transportation and marketing systems in urban

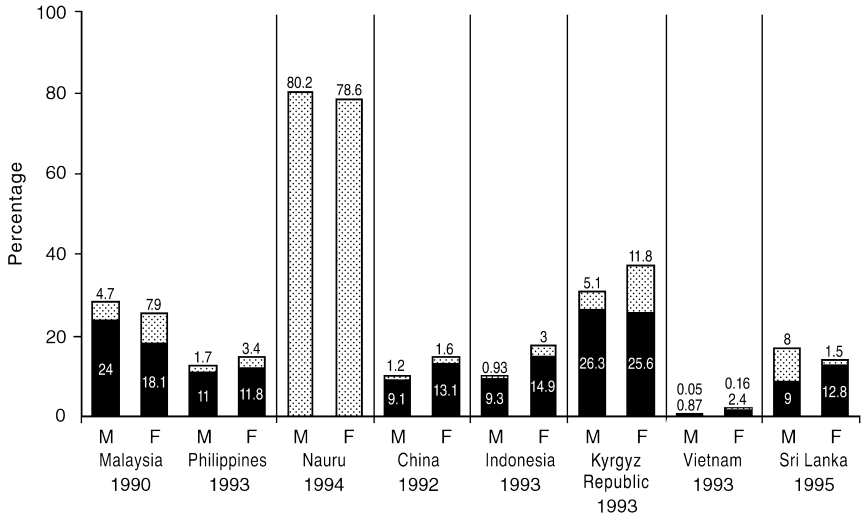

Figure 4. The prevalence of obesity in Asian countries by gender, 1990–1995. (▨), body mass index (BMI) ≥ 30 kg/m^2; (■), BMI 25–29 kg/m^2. Data from Popkin and Doak.[25]

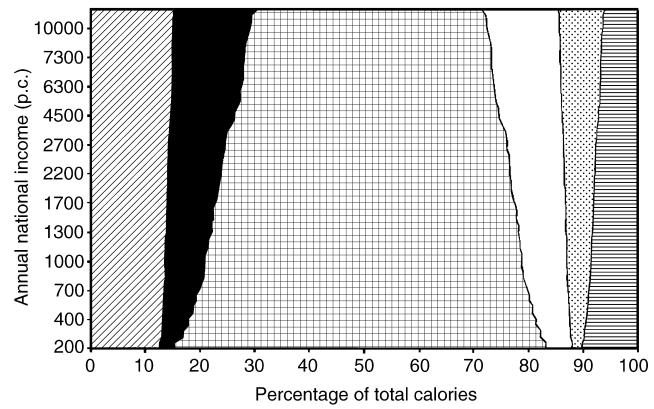

Figure 5. Relationship between the proportion of energy from each food source and gross national product (GNP) per capita with the proportion of the population residing in urban areas placed at 25%, 1990. (▨), vegetable fats; (■), animal fats; (▦), carbohydrates; (□), sweeteners; (▩), animal proteins; (▤), vegetable proteins. Data from Drewnowski and Popkin.[4]

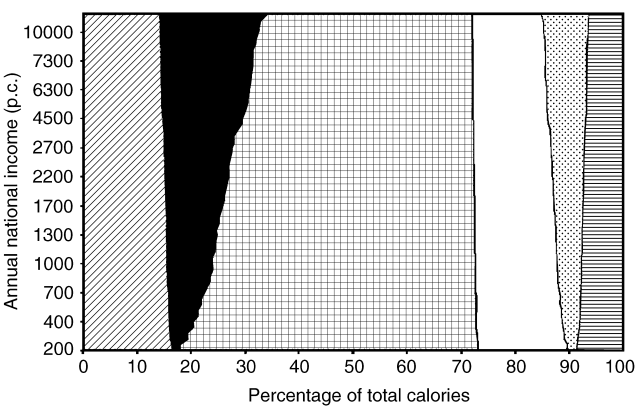

Figure 6. Relationship between the proportion of energy from each food source and gross national product (GNP) per capita with the proportion of the population residing in urban areas placed at 75%, 1990. (▨), vegetable fats; (■), animal fats; (▦), carbohydrates; (□), sweeteners; (▩), animal proteins; (▤), vegetable proteins. Data from Drewnowski and Popkin.[4]

areas, which provide greater availability of food during periods of seasonal shortage, greater penetration of marketing activities of the processed commercial food sector into the denser urban markets, greater heterogeneity of urban populations with respect to dietary patterns, different occupational patterns, characterized in urban areas by reduced compatibility of jobs with home food preparation and child and elder care, different household structures related to a wide range of economic and social factors and different disease and health service use patterns. (For a more detailed review of dietary aspects of urbanization, see Popkin and Bisgrove.[16])

Prices matter. Food prices play an important role in food selection, but are often ignored by health and nutrition professionals. Longitudinal dietary data collected as part of the CHNS in 1989–1993 from a sample of 5625 adults aged 20–45 years were examined. Three day averages of food group consumption and nutrient intake were used. The overall price elasticities were estimated for six food groups and three macronutrients. The results show very large and significant price effects. If the joint effects of the nutrition transition are to be considered, then there are clear trade-offs among which foods to tax and which to subsidize. Most important is the effect of prices in reducing fat intake of the rich but not adversely affecting protein intake for the poor. Increases in the price of pork, eggs and edible oils are shown to lower fat intake.[17] Only increases in pork prices lead to reduced protein intake. Figure 7 presents the effects of increasing prices of specific foods on the consumption of fat from each of these foods. It shows the greater price sensitivity of the poor and the effect that a change in the price of edible vegetable oil would have on fat consumption. Elsewhere, we show that increased prices for edible oil would increase protein intake, because Chinese adults replace edible oil with other foods that contain protein.[17]

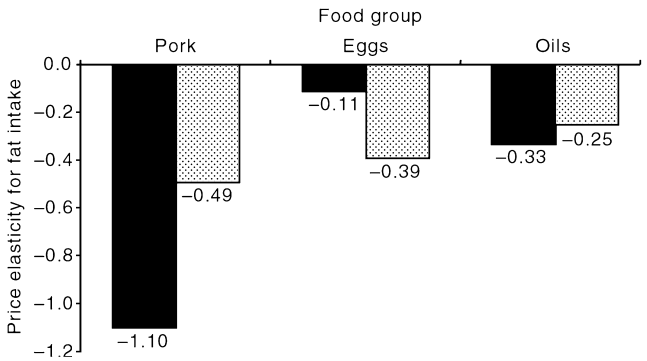

Figure 7. Effect of food price of various food groups on fat intake by poor (■) and rich (▨) Chinese men and women aged between 20 and 45 years. Data from Guo *et al.*[17]

Income relationships are changing. Elsewhere, we explore, in depth, the ways that income changes are affecting dietary intake and obesity in China and Brazil, respectively.[12,14] Figure 8 shows that, in urban areas, as income increases, the proportion of Brazilian women who are overweight is now decreasing. In addition, there are proportionately now more poor urban Brazilian women who are overweight than middle- and upper-income women.

The mass media are unknown components of the transition. Very little is known about the effects of rapid dissemination of information by the mass media in the developing world. What is clear, however, is that television ownership has skyrocketed in the developing world over the past 15 years. For example, in 1997, 89% of households covered by the CHNS owned television sets, more than double the proportion in 1989. In addition, programming in China now includes a wide range of international shows coming via Hong Kong, whereas in the 1980s no-one in China was exposed to foreign television programmes.

Fetal and infant insults

Barker *et al.* at the University of Southampton[18–20] have brought into the mainstream the notion of metabolic programming (i.e. that early insults operating at a critical period in development result in long-term changes in the structure or function of an organism). The effects are particularly apparent on the set of hormonal conditions termed syndrome X (obesity, hyperlipidaemia, adult-onset diabetes, hypertension and coronary heart disease). In the case of obesity, the hypothesis is that fetal growth retardation results in metabolic changes that are adaptive under nutritionally stressful circumstances *in utero*. A similar argument can be made for postnatal growth retardation manifested as stunting. As the child grows, the metabolic efficiencies that served well in conditions of undernutrition become maladaptive with overnutrition, leading to the development of abnormal lipid profiles, altered glucose and insulin metabolism and obesity.

Over the past several years, much research has shown that, for the programming to be expressed, it is clear that

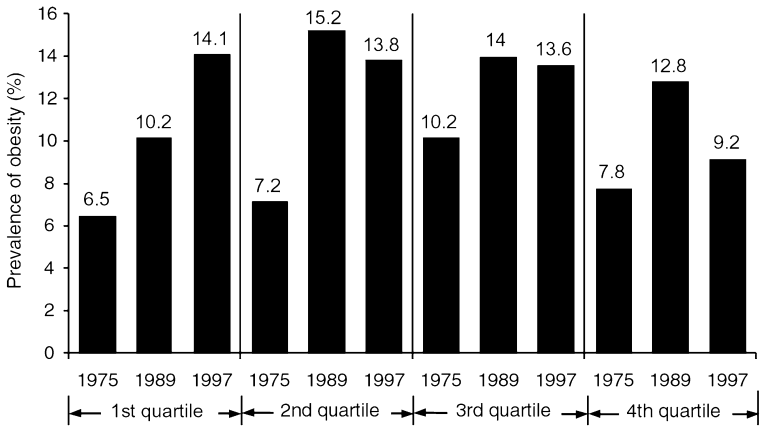

Figure 8. Obesity by income quartile in Brazil from 1975 to 1997. Data from Monteiro *et al.*[26]

subsequent conditions must provide the types of higher risks associated with these hormonal diseases (see a recent summary set of papers in a book commissioned by the National Institutes of Health).[21] That is, the results seem to show that programming enhances conditions linked with higher catch-up growth, greater obesity and reduced activity. There is controversy about the linkages; in fact, some argue that it is the catch-up growth and not the programming that may be the culprit, but this is very unclear to date.[22]

Adult-onset diabetes

The related clinical and epidemiological literature highlights the importance of the factors noted as being central to the nutrition transition, namely diet shifts, reduced physical activity and obesity, as also being critical determinants of adult-onset diabetes.[23,24] Diet is the least understood determinant of diabetes. The literature has clearly shown that in terms of mechanisms and epidemiology, obesity and activity are closely linked with adult-onset diabetes. Several reviews lay out the case for these factors. Zimmet *et al.*[23,24] have been particularly earnest in exploring these issues at the population level in a number of lower-income and transitional societies.

Summary

The nutrition transition addresses a broad range of socioeconomic and demographic shifts that bring rapid changes in diet and physical activity levels to most regions of the world. The changes are occurring most rapidly in lower-income countries, as is shown by the shifts in the distribution of the population, income and occupation patterns. Diet changes, most specifically the shift towards a diet with higher fat and meat and reduced carbohydrate and fibre, are also a shift towards more diverse and pleasurable diets. The activity patterns also represent a shift away from onerous labour-intensive activities. Thus, these dietary and physical activity shifts are desirable in many ways. Yet, they carry with them many unwanted nutritional and health effects. This paradox and complexity makes it difficult to understand how to act in order to arrest the negative aspects of the nutrition transition. It is also clear that we must view the causes of obesity as environmental rather than personal or genetic.

Acknowledgements. Funding for data collection and analysis was provided by the National Institutes of Health (NIH) (1RO1HD30880 and HD38700). Frances Dancy assisted in administrative matters, and Tom Swasey provided graphics support (Carolina Population Center, University of North Carolina, Chapel Hill, NC, USA).

References

1. Popkin BM. Nutritional patterns and transitions. Popul Dev Rev 1993; 19: 138–157.
2. Popkin BM. The nutrition transition in low-income countries: An emerging crisis. Nutr Rev 1994; 52: 285–298.
3. Popkin BM. The nutrition transition and its health implications in lower income countries. Public Health Nutr 1998; 1: 5–21.
4. Drewnowski A, Popkin BM. The nutrition transition: New trends in the global diet. Nutr Rev 1997; 55: 31–43.
5. Popkin BM. The nutrition transition in China: A cross-sectional analysis. Eur J Clin Nutr 1993; 47: 333–346.
6. Zhai F, Guo X, Popkin BM, *et al.* The evaluation of the 24 hour individual recall method in China. Food Nutr Bull 1996; 17: 154–161.
7. Popkin BM, Paeratakul S, Ge K. A review of dietary and environmental correlates of obesity with emphasis on developing countries. Obes Res 1995; 3 (Suppl.): S145–S153.
8. Food and Agriculture Organization. FAOSTAT.PC: Food Balance Sheets 1961–94. Rome: Food and Agriculture Organization of the United Nations, 1996.
9. World Bank. World*Data 1995. World Bank Indicators on CD-ROM. Washington DC: World Bank, 1995.
10. Paeratakul S, Popkin BM, Ge K, Adaur KS, Stevens J. Changes in diet and physical activity affect the body mass index of Chinese adults. Int J Obes 1998; 22: 424–432.
11. Monteiro CA, Mondini L, Medeiros de Souza AL, Popkin BM. The nutrition transition in Brazil. Eur J Clin Nutr 1995; 49: 105–113.
12. Monteiro CA, Conde WL, Popkin BM. Independent effects of income and education on the risk of obesity in the Brazilian adult population. J Nutr 2000 (in press).
13. Doak C, Adair LS, Monteiro C, Popkin BM. Overweight and underweight co-exists in Brazil, China, and Russia. J Nutr 2000; 130: 2965–2980.
14. Guo X, Mroz TA, Popkin BM, Zhai F. Structural changes in the impact of income on food consumption in China, 1989–93. Econ Dev Cult Change 2000; 48: 737–760.
15. Popkin BM. Urbanization, lifestyle changes and the nutrition transition. World Dev 1999; 27: 1905–1916.
16. Popkin BM, Bisgrove EZ. Urbanization and nutrition in low-income countries. Food Nutr Bull 1988; 10: 3–23.
17. Guo X, Popkin BM, Mroz,TA, Zhai F. Food price policy can favorably alter macronutrient intake in China. J Nutr 1999; 129: 994–1001.
18. Barker DJP, ed. Fetal and Infant Origins of Adult Disease. London: British Medical Journal Publishing Group, 1992.
19. Barker DJP. Mothers, Babies, and Disease in Later Life. London: British Medical Journal Publishing Group, 1994.
20. Barker DJP. Mothers, Babies and Health in Later Life, 2nd edn. London: British Medical Journal Publishing Group, 1997.
21. Barker DJP, ed. Fetal Origins of Cardiovascular and Lung Disease. New York: Marcel Dekker, 2000.
22. Lucas A, Fewtrell MS, Cole TJ. Fetal origins of adult disease: The hypothesis revisited. BMJ 1999; 319: 245–249.
23. Zimmet PZ. Kelly West Lecture: Challenges in diabetes epidemiology. From west to the rest. Diabetes Care 1991; 15: 232–252.
24. Zimmet PZ, McCarty DJ, de Courten MP. The global epidemiology of non-insulin-dependent diabetes mellitus and the metabolic syndrome. J Diabetes Complicat 1997; 11: 60–68.
25. Popkin BM, Doack CM. The obesity epidemic is a worldwide phenomenon. Nutr Rev 1998; 56: 106–114.
26. Monteiro CA, D' A Benicio MH, Conde WL, Popkin BM. Shifting obesity trends in Brazil. Eur J Clin Nutr 2000; 54: 342–346.