Global Changes in Diet and Activity Patterns as Drivers of the Nutrition Transition

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Abstract

The nutrition transition relates to broad patterns of diet, activity and body composition that have defined our nutritional status in various stages of history. The world is rapidly shifting from a dietary period in which the higher income countries were dominated by patterns of nutrition-related non-communicable diseases (NR-NCDs; while the lower and middle world were dominated by receding famine) to one in which the world is increasingly being dominated by NR-NCDs. Dietary changes appear to be shifting universally toward a diet dominated by higher intakes of caloric sweeteners, animal source foods, and edible oils. Activity patterns at work, leisure, travel, and in the home are equally shifting rapidly toward reduced energy expenditure. Large-scale declines in food prices (e.g., beef prices), increased access to supermarkets, and urbanization of urban and rural areas are key underlying factors.

The Nutrition Transition

The nutrition transition is defined as the shifts in the way we eat and move and subsequent effects on our body composition over the history of man. These broad shifts have occurred and continue to occur around the world in dietary and physical activity patterns. As noted elsewhere, much of the world's attention is focused on the three most recent patterns of the nutrition transition [1, 2]. Until the late 1980s, much of Asia and Africa followed a pattern of diet and activity linked with the 'pattern of receding famine'. Similarly, pockets of the population in Central America and much of South America and the Caribbean were living in a situation where undernutrition and communicable and parasitic diseases dominated. Today, there is a shift in the
way we move, eat and drink to a situation where even the poorest countries
and in most middle income transitional and all higher income countries, the
populations are dominated by the emergence of nutrition-related non-com-
municable diseases (NR-NCDs). A major health goal today is the move away
from this stage of the nutrition transition defined by ‘excessive NR-NCDs’
toward the ‘pattern of behavioral change’ where program and policy shifts
lead us back toward a healthier lifestyle and reduced adiposity and NR-NCDs.
In many ways we want to shift our dietary patterns closer to that of the early
hunter-gatherers which focused on plant foods and lean animal source foods.

Around the world, dietary shifts have occurred at various times and rates
of change. There are a number of major shifts that are occurring across the
lower and middle income world. Within each shift, however, the foods and
beverages driving the changes and even the eating behaviors are quite het-
erogeneous over space.

The Dietary Drivers: More Fats, More Added Caloric Sweeteners,
More Animal Source Foods

The Edible Oil Revolution

While a large shift toward increased consumption of edible vegetable oils
occurred in the higher income countries in the 1950–1980 period, edible oil has
been a major source of dietary change in the lower and middle income coun-
tries in the last several decades. The recent shift in the pattern of the nutri-
tion transition in developing countries typically begins with major increases
in the domestic production and imports of oilseeds and vegetable oils, rather
than meat and milk. Elsewhere, I have written in more depth about the tech-
nology behind this shift and the broader nature of these changes in both oil
seed extraction technology as well as breeding of new oil seed varieties con-
taining more oil [3]. Principal vegetable oils include soybean, sunflower, rape-
seed, palm, and groundnut oil. With the exception of groundnut oil, the global
availability of each approximately tripled between 1961 and 1990, and has
continued to increase since then though at a slightly reduced global pace.

This dramatic change arose principally from a major increase in the con-
sumption of vegetable fats. The intake of edible oil has increased consistently
over the past 15 years. In fact, in some developing countries we have docu-
mented an upwards shift in the income elasticity for all groups and a higher
one for the poor[4]. In table 1 we present data on the large increase in edible oil
intake in China where the major oils are soybean oil and rapeseed oil. The intake
for young adults more than doubled to close to 280 kcal of edible oil per day.

Caloric Sweeteners

Sugar is the world’s predominant sweetener though its history as the domi-
nant sweetener is only a few centuries old and there are now rapid increases
in many other caloric sweeteners. For this article we use the term ‘caloric sweetener’ instead of added sugar, as there is such a range of non-sugar products used today.

Globally, our research has shown that in 2000, 306 kcals were available for food consumption on a per person per day basis, about a third more than in 1962; caloric sweeteners also accounted for a larger share of both total energy and total carbohydrates consumed [5]. These global figures seem to greatly underestimate the consumption found when one uses detailed food composition data that measure the added sugar in each food item and measure nationally representative dietary intake data for any country. There are only a few countries that have the data to measure added sugar at the individual level and are presented in the examples below.

Figure 1 shows the relationship between the proportion of energy from different food sources and the gross national product for two different levels of urbanization [for a description of the analysis see, 3]. In figure 1a (the less urbanized case) the share of sweeteners increases sharply with income from about 5 to about 15%. In the more urbanized case (fig. 1b), the share is much higher at a lower income (>15%), and hardly increases with income.

We have measured added sugars much more carefully in the US diet. In a recent study we examined added sugars in all foods and beverages and the changes that occurred between 1965 and 2002. In the US there has been a very large increase in both the availability and consumption of high fructose corn syrup and added sugar since 1965 until a slight decline between 2000 and 2004. In the US today the average American consumes 377 kcal/day from added sugar. This represents 16.8% of all calories. Even more important,
among the top 20% of individuals, 896 kcal/person and day of added sugar was consumed [6].

What is most important is the shift in the US in the source of these kilocalories of added caloric sweeteners from foods to beverages. Coke and Pepsi
are global symbols of this shift in how we drink. We have seen a shift in the US since 1965 with a third of our caloric sweeteners coming from beverages to over two thirds. Essentially, in the US over the 1965–2002 period an added 228 cal/day came from caloric beverages and over two thirds of this shift are from sugared drinks [7].

Other countries that have studied aspects of added caloric sweeteners in our diets are Mexico and South Africa [8]. In Mexico, we have completed several analyses of caloric beverage patterns and trends. Mexican adolescents and adults consumed 20.1 and 22.3%, respectively, of their calories from caloric beverages. Whole milk, carbonated and noncarbonated sugared beverages, fruit juice with various sugar and water combinations added, and alcohol represented the four major categories of beverage intake. Unlike the US where soft drinks and other calorically sweetened drinks are dominant, in Mexico sugar added to an array of juice drinks is another major element [9]. A key aspect of Mexico is the more than doubling of intake of caloric beverages between 1999 and 2006 and the potential for far greater increases into the future. Figure 2 shows the trends in caloric beverage intake in Mexico. Another country where juice dominates as the source of caloric beverages is Australia [10].

The shift to beverages as the source of calories is particularly important because they do not sate us and there is an emerging consensus that calories from beverages are a potential source of energy imbalance globally [11]. This is true whether the calories come from high-fat, high-protein or high-carbohydrate beverages.

**Fig. 2.** Beverage consumption trends of Mexican adolescents and adult women, 1999 and 2006. High sugar is composed mainly of soft drinks, sweetened juices, agua frescas and alcohol; high calorie and low benefit is mainly whole milk, and low calories are slightly sweetened coffee and skim milk. Source: Barquera et al. [9] from nationally representative samples of the National Nutrition survey 1999 and 2006.
Animal Source Foods

The revolution in animal source foods refers to the increase in demand and production of meat, poultry, fish, and milk in low income developing countries. Delgado [12] has studied this issue extensively in a number of seminal reports and papers. Most of the world’s growth in production and consumption of these foods comes from developing countries. Thus, developing countries will produce 63% of meat and 50% of milk in 2020. By 2020, developing countries will consume 107 million metric tons (mmt) more meat and 177 mmt more milk than they did in 1996–1998, dwarfing developed country increases of 19 mmt for meat and 32 mmt for milk. 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.

Delgado [12] has shown that the share of the world’s meat consumed in developing countries rose from 37 to 48%, and their share of the world’s milk rose from 34 to 44%. Pork and poultry accounted for 76% of the large net consumption increase of meat in developing countries from 1982–1984 to 1996–1998.

There are different developing countries that dominate consumption for different animal products. China and Brazil play this role in meat consumption, while India is the key milk consumer. In the mid-1990s, Indian milk consumption amounted to 13% of the world’s total and 31% of milk consumption in all developing countries [12]. Table 1 provides data for trends in major components of animal source food intake in China. In China the increase in daily intake per day is over 38 g of animal source foods. Egg and diary intake have been particularly dramatic.

Underlying Eating Behaviors

While there has been extensive research on the economic, sociological, and demographic factors underlying these trends, the shifts in how we eat and how we prepare our food are equally profound, but poorly studied. The critical issues vary in their importance across the globe; however, it is clear that the changes seen in the US, Japan, and Europe are found globally at increasingly earlier stages of each country’s economic development. The key issues are:

- We eat more times in a day with snacking events shifting from episodically to 1–3 times/day
- The energy density of snacks has shifted upwards much faster than that for meals. Processed, fried salty snacks, and caloric beverages are the two dominant changes
- Processed foods are replacing unprocessed ones with a large shift toward refined carbohydrates
- Frying and grilling are replacing healthier elements such as boiling and steaming
Away-from-home consumption and preparation are dominating as the major growth elements and the art of cooking from natural ingredients is losing ground.

These trends have been studied extensively in higher income countries; however, few careful studies on these behaviors have occurred in the lower and middle income world [13, 14]. This is in large measure because the collection of nationally representative or large studies of individual dietary intake are infrequent in most low and middle income countries. For instance, India with a population of over a billion does not have a national nutrition monitoring system or any national dietary intake survey system. India does have nationally representative income and expenditure surveys and a rural survey in 9 states that collects limited dietary data. It also has had two nationally representative surveys that collected weight and height data for preschoolers and women of child-bearing age. This is true for many of the world’s largest countries. For instance, Brazil and Nigeria, two countries with over 178 and 124 million, respectively, do not have national dietary surveys. China and Mexico, in contrast, do have such nationally representative nutrition surveys that collect dietary data for all individuals.

Physical Activity Dynamics: Changes in the Technology of Work and Movement and Leisure

If individual dietary data are not collected in most low and middle income countries, there is a much greater scarcity of overall measures of physical activity and inactivity. The China Health and Nutrition Survey is one of the very few large scale surveys globally that collects detailed activity data from all age-gender groups. In higher income countries the focus is mainly on the collection of leisure activity and TV viewing, which represent a limited component of overall physical activity. As I show below, there is important variability in activity in all dimensions of life and each has important effects on energy imbalance.

Work at Home

While most of our focus has been on market work and the way this has changed, there are equally large shifts in home production. Time in food preparation has declined over the past half century from about 2 h/day to less than a half hour in the US and variable amounts elsewhere. A vast array of home production technologies from gas and electric stoves to microwaves, cuisinarts, rice cookers, and pressure cookers have reduced the time and effort required in food preparation. The vacuum cleaner, washing machine, and refrigerator have cut time in cleaning and shopping. As Chinese households have obtained these assets, we have found a significant weight gain associated with them [15].
Market Work

Economic work or market work represents one of the areas with the largest shifts in energy expenditures at the population level. The proportion of individuals working in energy expenditure-intensive jobs such as farming, mining, and forestry is way down while manufacturing has increased slightly, but the major shift is toward lower activity service sector jobs. Both lower income and higher income countries have experienced this shift [16]. Equally important has been a major shift in the activity of all occupations. New technology – be it small gas tractors or spraying systems for insecticides for farmers, or computers, faxes for service sector jobs – have led to major declines in activity at the same jobs. For instance, over the 1989–2006 period the proportion of urban Chinese in occupations with light levels of activity has increased from 24.7 to 40% of adults in the 20–45 year age group (table 1) [17].

Transport Shifts from Active to Passive

In most countries the proportion of individuals walking to work or shopping and other activities has declined drastically. In China the shift is from walking and biking to bus, motorcycle, and car use. These shifts again more than double the risk of overweight [18]. There is a great deal of discussion about active transport, namely walking and biking, as a key dimension of activity to promote. However, only in a few high income countries do we have measures of the effects of walking or biking on weight dynamics.

Leisure Is a Major Global Focus for Obesity Control but Is It Earned

We focus far too much attention on attempting to enhance our activity by active leisure pursuits while ignoring all the other dimensions of movement during the day. Part of this is related to the extensive focus on TV viewing. A vast literature has linked TV viewing with increased weight gain; however, most of this has focused on high income countries and there are few studies in higher income countries of other dimensions of activity [19, 20]. In higher income countries there is a focus on promoting walking as a leisure activity. Research at University of North Carolina on women followed for 15 years has shown that walking 2 h/week is linked with 4 kg less weight gain than among those with no walking [21].

There is surprisingly little research in higher income countries of the effect of home production, market work, or even transportation shifts on weight dynamics.

Underlying Environmental Reality

Crime, Pollution and Traffic

Keeping children at home to protect them from crime and the dangers of heavy traffic have been shown to be important in selected studies. For
example, in the US, crime has been found to be a key determinant of not just the level of reduced moderate to vigorous physical activity, but also of increased TV viewing time [22–24].

**Urban Design**

The creation of cities and smaller communities with a focus on low connectivity neighborhoods lacking sidewalks and encouraging car use is a common focus. A large number of studies have suggested this is a major issue, but some recent research suggests this might not be such a clear-cut issue [25, 26].

**Household Time-Saving Assets and Television Sets**

Television and dozens of other time-saving assets represent a major change in the lower and middle income world. The changes in China mirror those throughout Asia. Virtually every household in China has a television set. In fact, by 2006 over 95% of the households had color TV sets. Similarly, the proportion of households with washing machines doubled to almost 73% and the proportion with refrigerators increased to more than half of the households (table 1).

**Conclusions**

Clearly there is great potential that both dietary and physical activity and inactivity patterns are drivers of the growing global shift from a nutrition transition pattern associated with undernutrition to one linked with obesity and other NR-NCDs.

In the dietary area we have limited evidence of trends in eating behavior across the globe; however, there are far less data on overall activity and inactivity pattern trends. We have extensive data on total leisure time and TV viewing but little else.

**References**

Discussion

Dr. Agarwal: The experiences from China and other countries have been very illuminating. Over 1.3 billion people are overweight, and there is a pattern of nutrition transition in terms of more caloric and fat food and lesser activity, which is really hazardous to health. You gave an example of how things can be improved; in Australia the increase in obesity is 1.3%/year and in Mexico 1.9%. In Mexico the consumption of soft drinks and other caloric beverages was very high, but now there is a shift to using skim milk. So there is a way to improve things. This lecture opens many questions.

Dr. Prentice: I want to go straight to your challenge at the end of your talk. You painted an overwhelming picture of a global juggernaut. How are we going to turn that
around? You clearly said that there will be different approaches in different nations and that is well taken. But I wonder if you could start by pointing out some countries in which the obesity rates have at least stabilized or may be decreasing, and trying to show what lessons we might learn from those?

Dr. Popkin: To the best of my knowledge there is only one country in which obesity rates are truly declining in a large segment of the population, and that is among educated women in Brazil, and that is only in two thirds of the Brazilian population, aside from the poor in the northeast. The data show that the rates have increased slowly in Scandinavia, but there is really not a single country where we've managed to turn it around and pull back on the adiposity increases. There are countries that are taking on very aggressive stances right now, for example Mexico. With the Mexican Minister of Health we set up a beverage guidance panel that essentially created a set of guidelines to cut calories from beverages and the country is very aggressively moving on them. Whole milk has already been replaced by 1.5% milk in programs that feed around 20 million people, and will move to 0.5%, close to skim milk, in a year. The same is being done in the schools there. The government is moving now to tax sugar added in beverages and fat added in milk. So Mexico is a country in which caloric beverages are a key part of their huge caloric increases, and it is aggressively taking it on. Today very few countries have the guts and focus of Mexico to try and directly regulate anything on at a national level, other than trying to regulate the mass media.

Dr. Sawaya: As you mentioned very well-educated Brazilian women decreased obesity by avoiding processed food as much as possible and going back to the old traditional staple Brazilian diet which is rice, beans, fruits, legumes. Brazil is also a tropical country where body image and high physical activity are very important. My question is about sweeteners. Were you talking about artificial sweeteners and how important do you think they are?

Dr. Popkin: The sweetener question is a very complex scientific issue today. We actually know very little about the role of sweeteners in our diet, and they are increasing immensely. The receptors that are affected by intense diet sweeteners are exactly the same receptors that are affected by the caloric sugars of all sorts. We understand where the receptors are in the brain and how they act for many other items to which we become both habituated and addicted, but in the case of sweeteners we don't know whether we get habituated to sweeteners and eat more over time or we don't. We have no sense of the long-term effects of exposure to sweeteners and how that changes how we consume. So it is an area that has not really been studied very much. Right now I am actually working on a review of that topic with a colleague of mine because I think it is a major public health concern that has been ignored.

Dr. Arora: While you dealt mostly with food, what is the relative contribution of food or calorie intake versus physical activity on the overall obesity epidemic?

Dr. Popkin: In some ways, the big question is always whether gluttony or sloth is causing the problem. The reality is that the entire world is reducing physical activity, but in a metabolic and energy balance sense we are still in fairly tight regulation. Consider that it only takes 20 cal/day to add 1 kg of weight in a year, so it doesn't take very much dysregulation. We need to realize that we are not extremely far off from energy balance; if we were, the world would be adding many kilograms of weight per year and we are not. Thus very small changes can make a big difference. However, looking at the question of prevention and the question of change, if a person is consuming a soft drink a day, let's say 120 kcal for 225 ml (8 oz), then consider how many kilometers that person must run to burn 120 kcal and you begin to understand the limitations of increased activity. So from that context you can begin to think about all these changes in our diet as we adopted processed foods and shifted from water and breast milk to caloric beverages. It would take a lot of extra activity to prevent the
energy imbalance that creates the problem, and from that point of view I think most of us in the nutrition community would recommend dealing more with the diet world. Now the food industry will tell you it is really physical activity, or they did for a long time, but in general most in our nutrition community would say cutting calories is the key. That is, dealing with the food intake side will be more effective than increasing physical activity to deal with whatever dysregulation we are finding.

Dr. D. Chaudhuri: Your studies were done in a sedentary population. What was the average calorie consumption of the population?

Dr. Popkin: First obviously age and gender differences are huge and the changes over time are equally great. So in a country like China, where my colleague and I have worked, and in other countries I have studied in, activity is decreasing and calories are decreasing in general. But relatively speaking, in the US we are now starting to see an increase in caloric intake for reasons I don’t understand. This has occurred in the US over the past 30 years. I haven’t seen that in any low income country, so it depends on the point in time. On the average for adults in China, we were perhaps talking of 2,400–2,800 cal in the 1980s, today we are talking about closer to 2,200–2,400 cal. Again there is such a huge range, urban, rural, income, region, that it is very hard to deal with average figures anymore, given the vast heterogeneity and energy expenditure as well as the source and the amount of calories.

Dr. Chittal: In most developed countries it has been seen that adult obesity precedes the onset of childhood obesity by perhaps a decade. Why is it that in developing countries like China and India we see a lot of childhood obesity, although it is a less than 1% increase over the last decade, but not much adult obesity?

Dr. Popkin: I am not sure if this is actually correct. My examination of the data from India as well as China, Vietnam, Indonesia, all from nationwide studies, indicates a faster increase in the prevalence of adult than childhood obesity. However, childhood obesity in lower income countries seems to be much more clustered among higher income families whereas poor adults are becoming more obese than rich ones. Thus some samples do find much more in children, but these come from clinics and such. Another issue is that our measurement of childhood obesity is very weak. We are using BMI now, it is not necessarily the best but it is the only option we have, and I don’t know what standard you are referring to in India because when I have used the International Obesity Task Force (IOTF) standards for India my point above holds. However, very often people are using weight for height and they are using −1/+1 z score and to compare adults and children, which is almost impossible. The IOTF tried to create a standard that uses a 25 cutoff for adults and a 30 cutoff for BMI and bring it backwards. But as we look at the figures it gets worse and worse as the subjects get younger relative to other measures. So to talk about where there is more, is very complex. In my experience in low income countries, we see later emerging childhood obesity. If it is seen earlier in India, it is probably among the stunted short Indians which is something we found a lot in other parts of the world where we have studied that same issue. I haven’t seen other studies that address the point you are raising. In all the other countries I have worked in where there are national standards and we try to use BMI for children and adults, you can’t compare the prevalence in children and adults but you can compare the rate of change and it is increasing much more slowly for children.

Dr. Ganapathy: I am a pediatric sleep consultant, so my interest is in the quality of sleep. As you mentioned activity and changes in nutritional trends, don’t you feel that we are sleeping less and hence there is more exposure to food? The internet, TV, and lack of sleep lead to a large sleep debt. Therefore during the day people are exhausted and sleepy and their physical activity goes down, which also contributes to obesity [1]. Unfortunately, one third of our population is obese and about 6,000 children die every day because of undernutrition in our country.
Dr. Popkin: First India has the largest absolute number of malnourished and low birthweight children in the world. You brought up several issues. One was the question of sleep deprivation and its effects, and the second was the issue of diet. The complexity with the sleep deprivation issue is we haven't clearly sorted out the causal relationship. How much is adiposity leading to sleep apnea and other problems that cause sleep problems, and how much are sleep, exhaustion and tiredness causing us to eat higher energy processed foods? We have yet to do interventions in the sleep area to try to sort out causality. It is clearly a concern but more important probably in a country like India would be the shift to caloric beverages and processed foods in urban areas. In Latin America and now in Southeast Asia and in the urban rest of the world and in the Middle East, we have moved to the point where first in Latin America over 70% of spending today goes for processed food from supermarkets. In other words people who 20 years ago consumed fresh unprocessed food are today spending 70% of their money on processed food. We don't fully understand what that shift means; how much of it is just refined carbohydrates and other things that come with it, and we don't understand the processing per se other than the components of the food. Clearly there is a huge shift going on and with it is coming a lot of added sugar, added fats and so forth in the food, that we are sure of. But I can't go beyond that and really talk about the major implications of this huge shift in our diet.

Dr. Wharton: You have said the move to animal food is a driver, why? Is it increased fat, or other food displacement or what?

Dr. Popkin: Clearly I was talking about the changes in calories and mixed calories and the increase in energy density, so I am not speaking of fat versus protein. We know in the nutrition world that protein sates and so a high protein diet it can fill and sate you. On the other hand we have another hypothesis and concerns about energy density in the diet and increases, and how that may matter. If you go from a complex carbohydrate diet to an animal food diet, and a diet with a lot more water from fruits and vegetables, to a higher energy-dense diet, there are potential effects. But the causality issue was not my focus. For that we need a set of studies, like those on caloric beverages, on these dietary shift effects on weight in the context of random controlled trials or very well-monitored longitudinal studies. I was not trying to use that to say that therefore consuming more meat causes more adiposity. I was trying to give a sense of the drivers in the change in calories and the change in the composition and the amount of calories. In light of all the research that has been done I would be the last person to say that by giving people a higher protein, higher animal source diet that calories can be lost; calories can be lost with any diet; it is a question of total calorie regulation, and so I wasn't speaking of that. In fact I wish I knew that answer but I don't.

Dr. Yajnik: You talked about all the precipitating factors like diet and physical activity. What could be the susceptibility underlying this? Your slides showed that some of the less developed countries have a very high prevalence of obesity compared to developed countries.

Dr. Popkin: What Dr. Yajnik was talking about was the susceptibility to diet and activity changes in different parts of the world. Essentially what we know is that Caucasians, Europeans of a Caucasian white background, have a very low amount of adiposity around the heart and liver for the same level of BMI compared to almost any other ethnic group in the world, in particular South Asians, and then after that a number of other groups in the world have much higher adiposity. For example Dr. Yajnik shows a wonderful slide of John Ludkin and himself, they both have a BMI of about 21 and John Ludkin has about a third the amount of body fat of Dr. Yajnik, and all of Dr. Yajnik's fatness is around the heart and liver, and the most in the areas that lead the quickest toward diabetes and all the other cardiovascular risk factors that we
are so worried about. Aside from Polynesians in parts of Asia, the reality is that at a lower BMI most East Asians, Southeast Asians and South Asians have a greater risk of most of the cardiovascular outcomes that we see. Now in a country like Mexico it is the same, and throughout South America people with a lower BMI are starting to get diabetes and are becoming very insulin-sensitive, and the problems start at a BMI 5–6 points below that seen in the US among White Americans and in England and other places where this has been studied. I think what you are talking about Dr. Yajnik, in terms of sensitivity to diabetes and hypertension, we see much more sensitivity among all groups in the world, aside from Caucasians.

Dr. Rahman: You have mentioned the way people eat in terms of location; sitting in front of a television or something else?

Dr. Shahkhalili: What is the impact of nutrition transition?

Dr. Popkin: These are two different issues. One is the question of movement and sedentarism. You can be sedentary for many reasons. In China children may be sedentary because they are studying, they are not in front of the TV, they are in front of books; in the Philippines and Mexico they are watching TV; sedentarism varies enormously. For adults it again varies across the globe; it just depends on each society. I was asked the question how the shift in the stage of the nutrition transition, where adults are overweight, how does that come back and have an effect on fetal development, and does that play into the long-term intergenerational effects. Clearly adiposity during pregnancy first has an effect on gestational diabetes and a number of other issues. Beyond that on intergenerational transmission, is there a genetic side or is there a behavioral side to that, is there a metabolic transmission, we really don’t know. We use adult obesity all the time as an indicator for child obesity but we have not sorted out the causes between behavioral, metabolic and even epigenetic kinds of issues. So I can’t answer your question.

Reference