Review

Upper Limits in Developing Countries: Warning Against Too Much in Lands of Too Little

Daniel J. Hoffman, PhD

Department of Nutritional Sciences, Rutgers, the State University of New Jersey, 26 Nichol Avenue, Room 228B, New Brunswick, NJ 08901

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Recent trends in dietary patterns have provided a confusing and sometimes contradictory statement about the state of nutrition throughout the world. On the one hand, undernutrition caused by caloric and micronutrient deficiencies are still prevalent in developing countries. On the other hand, obesity caused by excess caloric intake is increasing at alarming rates in most developed and some developing countries. At the center of this confusion is the desire by health ministries to provide sound nutritional advice to prevent chronic diseases. One approach is to provide upper limits for nutrients that may be harmful if consumed in large quantities. This policy may be effective and sound for those nations with a low prevalence of food insecurity, but for many countries, especially those with trouble ensuring an adequate intake of protein and micronutrient-rich foods, the use of upper limits may result in unknown and potentially harmful effects and lead to delayed improvement in overall nutritional status. To explore this idea, a recent study looking at the relationship between early undernutrition and risk for obesity in children living in the shantytowns of Sao Paulo, Brazil is reviewed. The focus of this study was to better understand how the long-term effects of undernutrition on health and later risk for chronic diseases. This study illustrates the precarious state of health in developing countries and provides the backdrop for a discussion on food security and the potential effects of establishing policies on food intake in unstable settings.

Key teaching points:

- Growth retardation is associated with chronic diseases in many countries and societies.
- Economic development in many countries is accompanied by changes in diet and activity that promote chronic diseases.
- While many countries have developed in the past 50 years, there continues to be a high prevalence of undernutrition throughout the world.
- While food security is still quite high in most developing regions, restrictions on food items is not warranted.

Nutrition Transition and Metabolic Programming

Recent observations in countries undergoing rapid economic development, such as Brazil, China, South Africa, and parts of the former Soviet Union, have reported that while undernutrition and food insecurity and acute infectious diseases continue to be highly prevalent, the prevalence of overweight and chronic metabolic diseases is increasing [1]. This apparent paradox is due to improved access to food, decreased physical activity, and the consumption of "Western" diets [2,3]. The combination of these factors, the "Nutrition Transition", create an environment that may predispose persons to becoming overweight or obese [4]. In particular, it has been found that urbanization and related dietary changes improve health to a certain extent, the also place a city-dweller at risk for hypertension, diabetes, and weight gain. In addition, the question has also been raised as to what extent undernutrition early in life may predispose a person to becoming obese.

Urbanization has considerable effects on the economic and physical well being of individuals across all socio-economic strata [5–7]. Urbanization is highly associated with several dietary and behavioral risk factors for not only chronic disease, but obesity as well [8–10]. Dietary changes associated with urbanization tend to center around a shift from a high intake of fruits, vegetables, and legumes and a low intake of processed

Address reprint requests to: Daniel J. Hoffman, PhD, Department of Nutritional Sciences, Rutgers, the State University of New Jersey, 26 Nichol Avenue, Room 228B, New Brunswick, NJ 08901. E-mail: dhoffman@aesop.rutgers.edu.

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foods and refined carbohydrates to a high intake of fats, processed foods and refined carbohydrates [3,8,10–12]. In terms of physical activity, it has been reported that persons from low socio-economic levels tend to find work primarily as day laborers or factory workers, leaving behind physically demanding work for more sedentary labor [1]. A low level of physical activity has been indirectly associated with weight gain and obesity in several developed countries. These changes in dietary habits and physical activity create an environment in which a person predisposed to weight gain could become obese. Recently, it has been reported that nutritional stunting (growth retardation attributed to undernutrition during childhood) is associated with obesity in developing countries [13–15], providing evidence in support of "metabolic programming."

The concept of "metabolic programming" suggests that nutritional insults experienced in utero or during early childhood result in permanent metabolic alterations that increase the risk for insulin resistance, hypertension, and obesity [16–20]. Barker et al. have reported several times on the association between low birthweight and increased risk for type 2 diabetes, hypertension, and obesity [21–23]. Stunting (growth retardation resulting from chronic undernutrition) has been associated with obesity later in life in several transitional countries, such as China, South Africa, and Brazil [14]. Physiologic reasons for these observations vary from improper muscle development that affects substrate oxidation and physical activity to poor development of food intake and satiety controls during critical periods.

Discussion of Brazil Study

To explore the long-term metabolic effects of undernutrition, we designed a research project to test the hypothesis that stunted children living in the shantytowns of São Paulo, Brazil have metabolic and behavioral risk factors for obesity compared to normal height children from the same shantytowns [24–26]. This study was a collaboration between the Tufts University School of Nutrition Science and Policy, the Federal University of São Paulo (UNIFESP), and the Dunn Nutrition Centre of Cambridge University. Funding for this study was obtained from the Nestlé International Foundation, Lausanne, Switzerland.

Organization of the Research Team and Protocol

This research project was organized with a staff of physiologists, epidemiologists, nutritionists, a pediatric endocrinologist, nurses, and a social worker. The principal investigator was Susan B. Roberts, PhD, Chief of the Energy Metabolism Laboratory at the USDA Human Nutrition Research Center on Aging at Tufts University. The metabolic research unit was incorporated into an already existing center for malnutrition treatment (CREN) under the direction of Ana Lydia Sawaya, PhD. All body composition measurements and blood analyses were conducted at the Hospital São Paulo, the teaching hospital of UNIFESP. Finally, analyses of the urine samples from the doubly labeled water protocol were analyzed at Cambridge University.

Recruitment and Screening

Children for this study were recruited by visiting neighborhood schools and after-school centers in neighborhoods the border major shantytowns. All children had their height and weight measured using a portable scale and stadiometer and birth dates were collected from school records. Children that lived in the shantytowns were selected into either the healthy or stunted group based on the following criteria:

Healthy group: Height for age Z-score (HAZ) > -1.50 according to NCHS data and weight for height Z-score (WHZ) > -1.00 and < 2.00.

Stunted group: Height for age Z-score (HAZ) ≤ -1.50 according to NCHS data and weight for height Z-score (WHZ) > -1.00 and < 2.00. Boys and girls for each group were selected equally to control for gender differences and all children were older than 7, but less than 12 years of age.

Parents who gave consent for his/her child to participate in the study signed an informed consent and children signed an informed assent, approved by both Tufts University and UNIFESP. Each child who agreed to participate in the study was examined by a pediatric endocrinologist to determine the presence of any acute or chronic disease that would prohibit the child from participating in the study (such as severe undernutrition, diabetes, precocious puberty, and Tanner stage above 1).

Data Collection

The research protocol was divided into two phases. First, the field phase was conducted in the shantytowns where each child was accompanied for 6 consecutive days. The daily food intake was weighed and recorded each day from approximately 0700 until 1800. After 1800, food intake was measured by a literate family member who had been instructed in food measurements and performed sample measurements using food models.

During the field phase each child had his/her total energy expenditure (TEE) measured using the double labeled water method. Briefly, each child was weighed the day prior to the dosing with doubly labeled water ($D_2\,^{18}O$) to determine the dose to be administered. The child was weighed again on the morning of the dose and a background urine sample was collected. Samples were then collected hourly for 5 hours post-dose and once a day on days 2, 3, 4, 6, and 7 post-dose. All samples were collected in 5mL freezer tubes, stored in a refrigerated container during the day, transferred to a freezer until transported to Boston where they were processed and sent via courier to the Dunn Nutrition Centre.

Results

The stunted children were shorter, lighter, and of equal age compared to the healthy children, as was expected by the design of this study. There was no difference in the two groups for percent body fat or BMI. There were no significant differences between the groups in the monthly income or parental height and weight.

We found no significant differences between the groups in terms of energy intake, macronutrient composition, or total and resting energy expenditure when adjusted for lean body mass, although we did observe significant differences with respect to substrate oxidation, food intake patterns, and physical activity.

First, under fasting conditions, we measured a lower respiratory quotient (RQ) in the stunted children compared to the control children. The RQ of the stunted children was 0.94 compared to 0.90 for the control children and suggests that for the stunted children, 25% of the non-protein fuel mixture oxidized was fat and 75% was carbohydrate compared to 34% as fat and 66% as carbohydrate for the control children. There was no significant difference in RQ during any part of the post-prandial period, although it did appear that the stunted children failed to increase their carbohydrate oxidation would be expected and was demonstrated by the control children.

Second, we observed that the stunted children, while expending significantly less TEE, consumed the same amount of energy compared to the healthy children. When expressed as kilojoules per unit body weight, the stunted children ate 324 kJ/kg versus 266 kJ/kg for the healthy children. With respect to total energy expenditure, the stunted children were consuming 5% more of their measured energy expenditure when provided with abundant food under controlled conditions in which food intake was strictly measured and standard recipes and foods were used. The healthy children consumed approximately 98% of their measured total energy expenditure under the same conditions.

Third, found that the stunted boys had a significantly higher level of physical activity compared to stunted girls and to both control boys and girls. While both sets of girls had lower levels of physical activity, approximately 2400kJ compared to 2600kJ for the control boys, the stunted boys expended approximately 3400kJ for physical activity.

The results of this study are perhaps the first human evidence that stunted children have metabolic and behavioral risk factors for obesity compared to healthy peers. While these data provide only a partial picture of the relationship between undernutrition and later risk for chronic disease, they are consistent with animal studies suggesting a combined effect of metabolic and behavioral abnormalities following recovery from undernutrition. Moreover, this study illustrates that food policies developed in nations with relatively little starvation or food insecurity may not be appropriate for those with a high prevalence of undernutrition, given the unknown and potentially negative metabolic and behavioral consequences following recovery from undernutrition.

Food Security in Developing Countries

Upper limits are, by definition, those intakes of specific foods or nutrients above which a person may be at an increased risk for chronic disease if consumed in excess for an extended period of time or toxicity if consumed in large quantities during acute periods. For upper limits to be established it is essential to show that the intake of specific nutrients at times exceed the recommended intakes as defined by bodies such as the Institute of Medicine. In developed countries, such as the US and Europe, the intake of some nutrients have exceeded those levels determined to be safe and above which limited data are available regarding potential long-term toxicity and adverse effects on health. Thus, it is entirely appropriate to advise these populations to maintain a health and not excessive intake of such nutrients.

On the other hand, for countries with a high prevalence of undernutrition, it is unclear whether or not providing such recommendations is warranted given that the intake of many nutrients is below the DRI for these nutrients. For example, iron deficiency is prevalent throughout developing regions, thus recommending an upper limit for iron may have unforeseen negative impacts on iron intake among groups with limited education and health care. Furthermore, the use of upper limits cannot and should not be applied broadly to a region or country, especially when food security is still highly prevalent throughout the developing world.

State of Food Security

The prevalence of undernutrition and wasting (defined as weight for height less than -1.5 Z-scores and -2.0 Z-scores according to the United State NCHS reference charts) has been decreasing throughout most part of the developing world. In Latin America and Asia the number of children who are undernutrished has declined from 2–3 million to less than 1 million over the last 40 years [27]. At the same time, the number of undernourished children in regions with civil unrest, such as Africa and the Middle East, has increased from 46 to almost 50 million children over the same time period.

Those countries that have not yet decreased the prevalence of undernutrition tend to be in regions that have suffered either wars or other forms of civil unrest that has prevented either sustained economic development or the proper distribution of food aid. This trend reflects many improvements in food delivery mechanisms, democratic rule that favors a more equal distribution of finances and available food, and aid provided by developed nations. Still, it is far too premature to conclude that undernutrition and starvation have ceased to be a problem in many part of the world.

UNICEF reported in 1995 that almost half of all deaths in children under the age of 5 years were associated with protein-energy undernutrition. At the same time, it was reported that the prevalence of anemia and iron deficiency in developing regions were 2–10 times higher than in Europe [28]. Thus, while starvation as witnessed in famines tends to be acute and sporadic, the widespread chronic, but generally minor, undernutrition of protein and micronutrients is still having a profound effect on children throughout the world.

While more than 200 million children worldwide are considered to be undernourished, it is without doubt that the state of food security is improving throughout many parts of the developing world. The decreased prevalence of undernutrition is associated with significant improvements in the health care systems, education, and introduction of food systems that promote energy intake. At the same time, these regions are experiencing some negative consequences of economic development, primarily the loss of traditional diets, increased intake of processed foods, and decreased physical activity, which all promote chronic diseases. Clearly, there is a precarious balance of needs that are to be considered when implementing new food policies. Moreover, while the changes described are occurring in most regions of the developing world, this is not the case for all and in most countries, the health care and food systems are still underdeveloped and are associated with low energy intake.

Food Intake Patterns in Developing Nations

The Food and Agriculture Organization (FAO) of the United Nations reported that the world food supply is increasing worldwide [27]. Comparing countries between 1963 and 2001 clearly shows that the majority of countries now have more than 2800 calories/capita/day to provide to their citizens. Whether or not this food is fairly distributed or available to all sectors of society is questionable and the food supply for some countries is still well below 2000 calories/capita/day. Thus, despite efforts undertaken more than 50 years ago, beginning with the Marshall Plan and the creation of the World Bank, many countries are still unable to provide enough food for their citizens.

If we look at specific foods, those commonly associated with chronic disease, it is clear that the intake in developing countries is far below even the DRI for these foods or nutrients. For example, egg intake is generally lower in developing countries compared to Europe and the United States [27]. Between 1970 and 2000, the intake of eggs in developed countries has remained relatively stable at 12–14 kilograms per capita per year (kg/C/y) from 1970 to 2000 while the intake in developing countries has increased steadily from 2kg/C/y to 7 kg/C/y. What is most striking about this comparison is that developing countries, despite increasing their intake almost 4-fold, is still consuming half of what developed countries consumed 30 years ago.

More importantly, it is essential to consider the nutritional importance of such foods since protein undernutrition is prevalent throughout developing countries and is associated with death in children under 5 years of age. Using eggs as an example again, compared to North America and Europe, the protein intake from eggs is less than half in South America and less than one-fifth in Africa, suggesting that protein sources other than eggs are important in their diets [27]. It also suggests that foods that may be labeled as unhealthy or "bad" may result in a decreased intake of foods that are providing a valuable source of nutrients and preventing disease.

Fat, a macronutrient that has received considerable attention given its positive association with obesity, heart disease, and cancer, has increased in terms of per capita intake in most developed regions. For example, there was a 38% increase in fat consumption in all developing regions, ranging from 22% in North American to 55% in the former Soviet Union [27]. Developing countries have experienced a greater increase in fat intake, averaging 78% increase, but still consume 50% of the per capita intake found in developed countries [27]. Thus, while the warnings against high fat intake have been heeded to a small degree in developed regions, the warnings have either not been communicated or are not followed in developing regions. Nonetheless, in the case of fat, such warnings against excess intake may not be warranted given the relatively low fat intake compared to countries with a high prevalence of heart disease and obesity. Still, as countries develop economically and undergo the nutrition transition, it may become more imperative that developing countries develop a policy to ensure that fat intake not become a health issue, either through promoting traditional diets that are low in fat or warning against foods that are high in fat, such as fast foods or processed foods.

Turning attention to the relative intake of selected nutrients, for persons living in impoverished parts of the developing world, recommendations for usual intake, such as the DRI, appear to be goals rather than reality. Using data collected from children living in the shantytowns of Sao Paulo, Brazil, the actual intake of fat, iron and zinc were either at or below the DRI for these nutrients. This would suggest that persons living in such communities are failing to consume even the recommended intake and are not yet in a position to require warnings against excess intake. In fact, the possibility may exist for an actual decrease in intake of certain foods that are nutritionally beneficial if food policy changes support upper limits.

Suitability of Upper Limits

This discussion leads to the question of whether or not upper limits on specific foods or nutrients are suitable for developing countries. Based on available data, many developing countries are not experiencing the nutrition transition, in fact, most are still experiencing a degree of food insecurity and low intake of many nutrients [29]. It would thus become necessary to consider potential negative effects of warning against excess intake of foods that are still providing only marginal, but nutritionally important, levels of protein and micronutrients.

An example of the delicate nature of food policy and nutrient intake is provided by a study in China in which the price of pork was manipulated in an effort to reduce fat intake [30]. It was found that increasing the price of various foods associated with chronic disease, pork, eggs, and oils, resulted in a decreased intake of three foods. More important than overall reduction in food intake is the fact that members of the lower income groups showed a greater degree of negative price elasticity for foods that provide not only protein, but calories. This would suggest that artificially manipulating prices of these products increases the likelihood of protein and/or caloric deficiency if these food products are major sources of protein and calories. Thus, it would be an ill-advised food policy to modify food intake for an entire population through priced adjustments if the impact of lower income groups, those vulnerable to undernutrition and food insecurity, are not examined.

Another example of unforeseen collateral effects of food policies and recommendations is the change in dietary patterns following the campaign to reduce fat intake in the US. During the 1970s and 1980s, when data was being published showing that high fat diets are associated with not only heart disease and stroke, but also with weight gain and obesity, the US was barraged with campaigns to limit fat intake and to reduce the intake of foods high in fat. Most dietary data from this end of the 20th century support the conclusion that Americans did reduce their fat intake [31,32]. Recent data, however, suggest that the reduced fat intake was accomplished through the increased intake of carbohydrates, the majority of which were processed carbohydrates [32]. A study from Minnesota reported that between 1980 and 1992, a time during which the "low-fat" campaigns were active, protein intake did not change, fat intake decreased by 4.8% and carbohydrate intake increased by 5.8% [33]. This apparent over-compensation for reducing fat intake by increasing carbohydrate intake also resulted in an apparent increase in total energy intake. This change, without an accompanying increase in physical activity, is very likely associated with the recent obesity trends experienced by the US population.

Summary and Conclusion

There is still a high prevalence of undernutrition in many parts of the world. The fact that current efforts to reduce undernutrition have improved, but not yet remedied, the problem of food insecurity suggests that more efforts need to be taken to provide access to healthful food in a more egalitarian manner. At the same time, it is important to consider that many formerly low income countries are undergoing rapid development. Along with this development comes dietary changes that are associated with increased intake of calories and processed foods. Thus, it is not unreasonable to begin exploring food policies that promote healthful eating, but it may be premature to establish upper limits on specific foods that still contribute a substantial portion of daily energy and protein intake. The use of upper limits in developing countries, therefore, could have profound negative effects on the delicate balance of health and disease that exists in these regions.

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