Addressing Malnutrition to Improve Global Health
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# Addressing Malnutrition to Improve Global Health

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Malnutrition is a complex topic that affects different communities and different populations in a variety of ways. Given its many faces, adequate data to address this serious condition is essential if solutions are to be found. Defining exactly what malnutrition is (or isn’t) has also been a challenge. However, there is agreement that malnutrition is an issue of critical importance around the globe.

All too often, the words malnourished and starving are considered synonymous. To be sure, the sight of the swollen bellies and skeleton-thin arms of undernourished children is heart-wrenching. But this does not tell the full story. Malnutrition is not exclusively a problem of extreme poverty, nor only of the young, but affects all communities around the world and people of all ages.

Four particular facets of malnutrition are often overlooked. The first is that of inadequate nutrition seen in the elderly, an important issue that has become particularly problematic in Asia and many developing countries around the world. The latest evidence shows an awareness gap in health care workers and the broader community when it comes to the extent and implications of malnutrition in the elderly. Too often, aged hospital in-patients are not properly assessed for nutritional insufficiency either at admission or during their stay, seriously complicating and prolonging their treatment.

Disease-associated malnutrition (DAM) is also an increasingly urgent issue, not in the least because it places significant economic burden on countries. DAM can often be due to chronic conditions or conditions prevalent in aging populations. Its impact, however, is not limited to historically wealthy nations. China faces an increasing challenge from DAM as its population rapidly ages, with estimates in the billions of dollars annually.

Thirdly, overnutrition, or obesity, is another underrecognized malnutrition condition, one that is of particular concern in developed nations. Since proper nutrition is a balance of macro- and micronutrient intake and adsorption, overnutrition can cause nutritional insufficiencies in essential nutrients, leading to a range of negative health consequences including diabetes, cancer, and cardiovascular disease.

Finally, maternal malnutrition has been associated with lifelong nutritional issues, a process known as fetal programming.

These issues, and more, are discussed in some depth in this publication, which brings together important research articles previously published in Science with original articles, all from top researchers and thought leaders in the field. This booklet is intended to be a call to action for the scientific, academic, governmental, and medical communities to assess and address the economic and clinical burden that malnutrition (in all of its forms) exerts on the global economy and to find a means to provide both short- and long-term solutions for those suffering from malnutrition and its consequences.

Sean Sanders, Ph.D.
Editor, Custom Publishing, Science/AAAS
Nutrition is vital for health at all ages. Inadequate nutrition intake and poor diets can result in malnutrition, an underrecognized and undertreated condition with significant consequences on global health. Malnutrition is multifaceted and far reaching, existing in both developed and developing countries, in health care situations, and out in the community. The challenge is great and the need for solutions is immediate. Malnutrition is an often hidden problem for our health care systems. The numbers are staggering: Even in the most well-developed health care systems in the world, up to 50% of patients are malnourished or at risk. Those who enter the hospital malnourished heal more slowly and are much more likely to be readmitted. Nutrition, while critical to healing and recovery, is often overlooked. Research shows that simply providing an oral nutrition supplement can reduce readmissions, complications, length of hospital stay, and mortality.

The challenge of malnutrition exists across the lifespan. Even before we are born, nutrition intake impacts our development. As children, nutrition enables our physical and mental development, and growth. As adults, nutrition supports a healthy and active lifestyle. And as we age, nutrition extends physical and mental health resulting in longer and higher quality independent living. Malnutrition—at any stage—can take away these fundamental elements.

Malnutrition can have a ripple effect across countries, their economies, and their health care systems. For example, China has both the world’s largest population, and also one undergoing dramatic change. By the year 2040, the Chinese population will grow by an additional 300 million people. China’s rapid growth and overall aging of the population is creating health care and healthy living challenges that never before existed, but now require near-term solutions. Malnutrition is one of these challenges. Fortunately it can be fully preventable and treatable whether occurring in a hospital setting or in the community.

At Abbott, we are committed to being part of the solution to improve health outcomes for patients with malnutrition. Our work centers on two streams. First, we are actively engaged in the emerging field of health economics and outcomes research (HEOR) to quantify the health economic benefits of nutrition. Secondly, we are acting on these findings by developing and clinically validating new solutions to address the greatest needs.

For example, we have quantified the economic impact of malnutrition for the U.S., Europe, and China in key populations, setting the groundwork for additional research to understand the cost-effectiveness of different nutritional interventions of the most prevalent diseases.

The cycle of hospital admission from the community and back to the hospital can be prevented when health care providers address a patient’s nutrition status, beginning at their admission. Simply stated, early nutrition intervention can help lower costs and improve patients’ health and quality of life.

Solving this complex issue of malnutrition and health outcomes requires collaboration between many stakeholders, including health care, academic, industry, and government leaders. This collaboration will lead to solutions which extend and expand the quality of life for the people around the world.

We at Abbott Nutrition ask you to learn more about the issue and partner with us in making strides against malnutrition. We look forward to being an active part of this complex solution and thank you for your interest in our research. Together, we can solve this problem.

Robert H. Miller, Ph.D.
Abbott Nutrition
Divisional Vice President, Research & Development and Scientific & Medical Affairs
Section 1: The burden and impact of malnutrition on public health

Malnutrition, a complex condition resulting from inadequate nutrition intake, is significantly impacting both developed and developing countries. Scarcity and security of food plays a critical role in the development of malnutrition. This condition has created a quantifiable, significant health care and economic burden on society, driven by growth and aging of the global population. The impact is greatest in key countries, such as China, where these rapidly changing demographics are reshaping the population and with it, the scope and burden of malnutrition. The following articles deal specifically with the significant challenges the world faces.
What is malnutrition? Different definitions exist, many of which are vague and of limited use for either clinical practitioners or researchers. The World Health Organization International Classification of Diseases 10 (ICD-10) defines it as a “body mass index (BMI) <18.5 kg/m^2 or unintentional weight loss of ≥5%, with evidence of suboptimal intake resulting in subcutaneous fat loss and/or muscle wasting.” The National Library of Medicine MESH definition states that malnutrition is “an imbalanced nutritional status resulting from insufficient intake of nutrients to meet normal physiological requirements.” The American Society for Parenteral and Enteral Nutrition and the Academy of Nutrition and Dietetics define malnutrition based on an imbalanced nutritional status and its relation to starvation, and acute and chronic disease conditions (1), while the European Society for Parenteral and Enteral Nutrition integrates both undernutrition and overnutrition into its definition.

Malnutrition encompasses a group of diseases that involve complicated patho-physiological mechanisms, making it a challenge for public health, especially in a developing country with a large population such as China. Malnutrition can become a burden for society and families, especially as the population ages. In China, 178 million people are over 60, constituting over 13% of the total population. The proportion of those who are 65 and older increased from 7.0% to 8.9% between 2000 and 2010, and is expected to exceed 10% by 2020 (2, 3), doubling to 20% by 2050 (4). To add to this burden, the number of hospitalized elderly patients is increasing in China (4-6) and malnutrition in the elderly is associated with poor outcomes, including mortality, postoperative morbidity, and extended hospitalizations.

Recent multicenter epidemiological surveys indicate that between 10% and 60% of all hospitalized Chinese patients suffer from malnutrition (4-6). The imprecise data suggests a lack of systematic screening and diagnosis for malnutrition. Some studies estimate that at least 17 million hospitalized elderly patients (~50%) suffer from malnutrition each year (Table 1) (5, 6). Malnutrition is therefore an important public health concern that requires appropriate responses from physicians, scientists, and health providers.

**Diagnostic challenges**

Early, accurate diagnosis is critical for malnutrition monitoring and intervention in the elderly. Although many screening tools are available, with more than a dozen in clinical use, none provide a comprehensive diagnosis that fully reflects the complex nature of malnutrition and its related metabolic components. Additionally, these tools have not been rigorously assessed for efficacy of diagnosis.

Many subconditions fall under the general diagnostic term “malnutrition.” Nutritionists and dietitians have attempted to provide some classifications, including protein-energy malnutrition, disease-related malnutrition, protein-energy wasting syndrome, and malnutrition with certain micro-nutrients deficiencies. However, there is currently no systematic organization that comprehensively integrates the various indicators such as nutrient intake, disease, body composition, metabolic disturbances, and pathophysiological processes (including inflammatory response and oxidative stress). In the past decade, Chinese physicians have become aware of the importance of malnutrition and attempts have been made to improve malnutrition diagnoses, including the introduction of the nutritional risk screening (NRS) 2002 tool. However, success has been limited. A robust diagnostic system is needed to integrate these variables and recognize different patterns of malnutrition.

A good malnutrition diagnosis should provide an objective, quantifiable measure based on clinical indicators; only then is effective and individualized intervention possible. None of the available nutritional screening or evaluation tools currently meet these criteria in terms of mathematically accurate. Ideally, the diagnostic framework that would incorporate physical symptoms, biochemical tests, and physiological evaluations to generate a single malnutrition score that accurately delineates and describes various types of malnutrition.

**A new diagnostic framework**

We suggest redefining the classification system for malnutrition to create “malnutrition ontology.” Ontological systems have been successfully applied in bioinformatics and computer science (10) and provide a powerful methodology for organizing and defining complex sets of heterogeneous data, a challenge when dealing with patient variability. In ontological terms, malnutrition could be deconstructed into individuals (instances), classes (concepts), attributes, and relations. Here, class defines the different types of malnutrition, while the attribute is used to quantify each class. The relation describes the relationships between the different categories of malnutrition.

Utilizing the enormous set of existing malnutrition survey data together with computerized pattern-recognition techniques, an artificial intelligence system could be

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developed capable of detecting the heterogeneous influence of malnutrition in different diseases. It could additionally provide information on malnutrition patterns and the efficacy of nutritional interventions. This process would enable more accurate malnutrition diagnosis as well as establish a monitoring system that could identify those most at risk of malnutrition and provide a rational basis for appropriate individualized intervention.

In addition to introducing multiple ‘omics techniques (such as metabolomics and transcriptomics), technologies such as cloud computing, social networks, and wearable health monitoring devices could enable solutions that promote patient adherence (11–13). This is especially critical for elderly patients. Information generated by social networks and collected using wireless technologies can provide big data sets, the analysis of which can help to optimize new diagnoses and monitoring systems. The low cost and prevalence of various sensors, as well as the growing popularity of smart phones, means that these solutions will be increasingly affordable for middle to low income countries.

In summary, we believe that the proposed malnutrition ontology will lead to better diagnosis, individualized intervention, and improved population monitoring of malnutrition in the coming decades, equipping doctors with new tools for the managing the challenge of aged health care in the 21st century.

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References

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<tr>
<td>10,181 in 4 big cities</td>
<td>Hospitalized elderly patients</td>
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Nutrition insecurity and malnutrition in developed countries

Susan Finn

We are familiar with the face of malnutrition in developing countries where men, women, and children suffer from bloating and body ulcers caused by protein deficiency (kwashiorkor) and the wasting that results from inadequate energy intake (marasmus). These two markers for malnutrition, however, don’t tell the whole story.

This paper briefly examines the nature, drivers, and impact of malnutrition in the Western world and suggests some foundational steps to combat it.

The big picture

Nutritional health depends on an intricate balance of macro- and micronutrients. There is no one foolproof clinical test for malnutrition, and we don’t always recognize it when we see it. According to the Academy of Nutrition and Dietetics, malnutrition can be defined as any nutritional imbalance, whether it be a lack of calories needed to meet the body’s energy demands or a lack of vital nutrients (1).

A recent United Nations Food and Agriculture Organization publication, The State of Food Insecurity in the World 2014, reported that more than 790 million people (15% of the population in developing countries) have an insufficient amount of food available to meet basic energy needs. In developed countries, that number drops dramatically to just short of 15 million (<5% of the population) (2). Malnutrition, however, is not a one-dimensional issue. It is as much about hunger—getting enough calories (quantity)—as it is about the macro- and micronutrient density of those calories (quality). Thus, a malnourished person may be extraordinarily thin and gaunt, as in the pictures we see of starving third-world children, or may be overweight/obese. In the Western world and in rapidly developing emerging countries, we are seeing more and more of the latter.

Nutrition insecurity

Codifying the definition of malnutrition to reflect not only the impact of too few calories in the diet, but also the ramifications of too few nutrients, demands that we take a closer look at root causes. Food insecurity is not the only roadblock to eliminating malnutrition; nutrition insecurity is equally as challenging. While extreme hunger leading to malnutrition does occur in developed countries, it is not equivalent to the same issue in developing nations; however, nutrition insecurity—lack of nutrient density in calories consumed—is a worldwide problem. For example, the 2010 Dietary Guidelines for Americans (for the population as a whole) identifies four shortfall nutrients in the U.S. diet: fiber, calcium, potassium, and vitamin D. Canada and the European Union have similar guidelines (3).

The inability to access, purchase, and prepare nutritious food can have serious short- and long-range consequences for the health care system as well as the economy and society as a whole. Infants (including fetuses in utero) and children who experience nutrition insecurity may face developmental delays, poor health outcomes, and educational challenges. These children enter the workforce ill prepared to be fully productive and to earn a living wage. Adults who experience nutrition insecurity face the risk of increased acute illness and chronic disease. The resulting dip in productivity and rise in sick days make them less likely to succeed in the competitive marketplace. Seniors experiencing nutrition insecurity may face an accelerated decline in cognitive function as well as an increase in chronic disease, both of which stress the health care system.

Challenges

In the United States, key drivers behind food and nutrition insecurity include poverty, nutrition illiteracy, and resistance to agricultural biotechnology.

Poverty

A 2013 Pew Research Global Attitudes Center survey revealed that, despite their country being the wealthiest in the survey, almost a quarter of Americans said they had had trouble putting food on the table during the prior 12 months. This rate is up from 16% in 2007, the year the Great Recession began (4).

Researchers Walter Willett, Frank Hu, and colleagues, reported in the September 2014 issue of JAMA Internal Medicine that the quality of the American diet had improved from 1999 to 2010. They also observed that people with higher socioeconomic status had healthier diets than those with lower socioeconomic status, most likely due to the price of and access to healthier foods. In addition, they noted that dietary quality was lowest and improved more slowly among people who had had 12 years or less of school (5).

Nutrition illiteracy and confusion

Academy of Nutrition and Dietetics surveys show that while almost 90% of consumers say that nutrition is very important to them, less than 50% believe they are doing all they can eat a balanced, nutritious diet and only 40% say they know and understand the guidelines for healthy eating (6). In International Food and Information Council polls, 75% of consumers say that ever-changing nutrition information makes it difficult to know what to believe (7).
Resistance to agricultural biotechnology

Advances in science have created new opportunities for the agricultural community to meet global food and nutrition security demands and environmental/sustainability challenges. Agricultural biotechnology—including genetically modified organisms and livestock vaccines—helps increase productivity by reducing crop and animal damage. These advances, however, are not without controversy. As agricultural biotechnology continues to evolve, the application of sound science and civil discourse are needed to ensure biotech crops and livestock produce safe, nutrient-rich foods.

Responding to nutrition insecurity

Government, professional, and grassroots innovation is needed to promote nutrition security. These examples from the United States represent the kind of infrastructure found in developed countries.

Safety net

The U.S. government provides a food and nutrition safety net focused on protecting society’s most vulnerable people—infants, children, and seniors. This extensive support network includes free and reduced-price school nutrition programs for children of all ages and economic means; senior feeding programs; food distribution programs; food stamps (Supplemental Nutrition Assistance Program, a.k.a., SNAP); and the Special Supplemental Nutrition Program for Women, Infants and Children (WIC).

Nutrition literacy

Initiatives such as the Academy of Nutrition and Dietetics literacy programs, its Future of Food campaign and its partnership in the Alliance to Advance Patient Nutrition, address the need to improve not only the public’s working knowledge of nutrition in the food system, but also health care professionals’ understanding of the role of nutrition security in preventing and treating disease.

Innovation

Continuous and transparent multidisciplinary partnerships to research, test, evaluate, and report on innovations in food and nutrition security, agriculture, biotechnology, health promotion, and disease prevention up and down the food system spectrum are necessary to leverage knowledge and resources, promote expert dialogue, and enhance sustainability. The 10-member bipartisan National Hunger Commission, convened in 2014, is currently exploring ways to encourage public-private partnerships and greater involvement from community and faith-based groups in providing a food and nutrition safety net for the poor. For example, in Indianapolis, Indiana, the Indy Hunger Network is a model grassroots coalition of local businesses; advocacy groups; food banks; WIC, SNAP, and child nutrition programs; senior groups; and faith communities that aims to reduce hunger and promote nutrition security.

Food and nutrition insecurities that escalate into malnutrition in developing nations as well as in developed countries such as the U.S. present a multifaceted challenge. Economic, social, and cultural variables render one-size-fits-all solutions futile. This is not to say, however, we cannot learn from each other. In fact, we must learn from each other through hands-on multidisciplinary, multinational joint ventures, partnerships, coalitions, and alliances from the grassroots to the highest level of policymaking.

References

Continuing population and consumption growth will mean that the global demand for food will increase for at least another 40 years. Growing competition for land, water, and energy, in addition to the overexploitation of fisheries, will affect our ability to produce food, as will the urgent requirement to reduce the impact of the food system on the environment. The effects of climate change are a further threat. But the world can produce more food and can ensure that it is used more efficiently and equitably. A multifaceted and linked global strategy is needed to ensure sustainable and equitable food security, different components of which are explored here.

The past half-century has seen marked growth in food production, allowing for a dramatic decrease in the proportion of the world’s people that are hungry, despite a doubling of the total population (Fig. 1) (1, 2). Nevertheless, more than one in seven people today still do not have access to sufficient protein and energy from their diet, and even more suffer from some form of micronutrient malnourishment (3). The world is now facing a new set of intersecting challenges (4). The global population will continue to grow, yet it is likely to plateau at some 9 billion people by roughly the middle of this century. A major correlate of this deceleration in population growth is increased wealth, and with higher purchasing power comes higher consumption and a greater demand for processed food, meat, dairy, and fish, all of which add pressure to the food supply system. At the same time, food producers are experiencing greater competition for land, water, and energy, and the need to curb the many negative effects of food production on the environment is becoming increasingly clear (5, 6). Overarching all of these issues is the threat of the effects of substantial climate change and concerns about how mitigation and adaptation measures may affect the food system (7, 8).

A threefold challenge now faces the world (9): Match the rapidly changing demand for food from a larger and more affluent population to its supply; do so in ways that are environmentally and socially sustainable; and ensure that the world’s poorest people are no longer hungry. This challenge requires changes in the way food is produced, stored, processed, distributed, and accessed that are as radical as those that occurred during the 18th- and 19th-century Industrial and Agricultural Revolutions and the 20th-century Green Revolution. Increases in production will have an important part to play, but they will be constrained as never before by the finite resources provided by Earth’s lands, oceans, and atmosphere (10).

Patterns in global food prices are indicators of trends in the availability of food, at least for those who can afford it and have access to world markets. Over the past century, gross food prices have generally fallen, leveling off in the past three decades but punctuated by price spikes such as that caused by the 1970s oil crisis. In mid-2008, there was an unexpected rapid rise in food prices, the cause of which is still being debated, that subsided when the world economy went into recession (11). However, many (but not all) commentators have predicted that this spike heralds a period of rising and more volatile food prices driven primarily by increased demand from rapidly developing countries, as well as by competition for resources from first-generation biofuels production (12). Increased food prices will stimulate greater investment in food production, but the critical importance of food to human well-being and also to social and political stability makes it likely that governments and other organizations will want to encourage food production beyond that driven by simple market mechanisms (13). The long-term nature of returns on investment for many aspects of food production and the importance of policies that promote sustainability and equity also argue against purely relying on market solutions.

So how can more food be produced sustainably? In the past, the primary solution to food shortages has been to bring more land into agriculture and to exploit new fish stocks. Yet over the past 5 decades, while grain production has more than doubled, the amount of land devoted to arable agriculture globally has increased by only ~9% (14). Some new land could be brought into cultivation, but the competition for land from other human activities makes this an increasingly unlikely and costly solution, particularly if protecting biodiversity and the public goods provided by natural ecosystems (for example, carbon storage in rainforest) are given higher priority (15). In recent decades, agricultural land that was formerly productive has been lost to urbanization and other human uses, as well as to desertification, salinization, soil erosion, and other consequences of unsustainable land management (16). Further losses, which may be exacerbated by climate change, are likely (7).

Recent policy decisions to produce first-generation biofuels on good quality agricultural land have added to the competitive pressures.
Thus, the most likely scenario is that more food will need to be produced from the same amount of (or even less) land. Moreover, there are no major new fishing grounds: Virtually all capture fisheries are fully exploited, and most are overexploited.

Recent studies suggest that the world will need 70 to 100% more food by 2050 (1, 18). In this article, major strategies for contributing to the challenge of feeding 9 billion people, including the most disadvantaged, are explored. Particular emphasis is given to sustainability, as well as to the combined role of the natural and social sciences in analyzing and addressing the challenge.

**Closing the yield gap**

There is wide geographic variation in crop and livestock productivity, even across regions that experience similar climates. The difference between realized productivity and the best that can be achieved using current genetic material and available technologies and management is termed the “yield gap.” The best yields that can be obtained locally depend on the capacity of farmers to access and use, among other things, seeds, water, nutrients, pest management, soils, biodiversity, and knowledge. It has been estimated that in those parts of Southeast Asia where irrigation is available, average maximum climate-adjusted rice yields are 8.5 metric tons per hectare, yet the average actually achieved yields are 60% of this figure (29). Similar yield gaps are found in rain-fed wheat in central Asia and rain-fed cereals in Argentina and Brazil. Another way to illustrate the yield gap is to compare changes in per capita food production over the past 50 years. In Asia, this amount has increased approximately twofold (in China, by a factor of nearly 3.5), and in Latin America, it has increased 1.6-fold; in Africa, per capita production fell back from the mid-1970s and has only just reached the same level as in 1961 (2, 20). Substantially more food, as well as the income to purchase food, could be produced with current crops and livestock if methods were found to close the yield gaps.

Low yields occur because of technical constraints that prevent local food producers from increasing productivity or for economic reasons arising from market conditions. For example, farmers may not have access to the technical knowledge and skills required to increase production, the finances required to invest in higher production (e.g., irrigation, fertilizer, machinery, crop-protection products, and soil-conservation measures), or the extreme cases of failed states and nonfunctioning markets, the solution lies completely outside the food system. Where a functioning state exists, there is a balance to be struck between investing in overall economic growth as a spur to agriculture and focusing on investing in agriculture as a spur to economic growth, though the two are obviously linked in regions, such as sub-Saharan Africa, where agriculture typically makes up 20 to 40% gross domestic product. In some situations, such as low-income food-importing countries, investing purely in generating widespread income growth to allow food purchases from regions and countries with better production capabilities may be the best choice. When investment is targeted at food production, a further issue is the balance between putting resources into regional and national infrastructure, such as roads and ports, and investing in local social and economic capital (21, 22).

A yield gap may also exist because the high costs of inputs or the low returns from increased production make it economically suboptimal to raise production to the maximum technically attainable. Poor transport and market infrastructure raise the prices of inputs, such as fertilizers and water, and increase the costs of moving the food produced into national or world markets. Where the risks of investment are high and the means to offset them are absent, not investing can be the most rational decision, part of the “poverty trap.” Food production in developing countries can be severely affected by market interventions in the developed world, such as subsidies or price supports. These need to be carefully designed and implemented so that their effects on global commodity prices do not act as disincentives to production in other countries (23).

The globalization of the food system offers some local food producers access to larger markets, as well as to capital for investment. At the aggregate level, it also appears to increase the global efficiency of food production by allowing regional specialization in the production of the locally most appropriate foods. Because the expansion of food production and the growth of population both occur at different rates in different geographic regions, global trade is necessary to balance supply and demand across regions. However, the environmental costs of food production might increase with globalization, for example, because of increased greenhouse gas emissions associated with increased production and food transport (24). An unfettered market can also penalize particular communities and sectors, especially the poorest who have the least influence on how global markets are structured and regulated. Expanded trade can provide insurance against regional shocks on production such as conflict, epidemics, droughts, or floods—shocks that are likely to increase in frequency as climate change occurs. Conversely, a highly connected food system may lead to the more widespread propagation of economic perturbations, as in the recent banking crisis, thus affecting more people. There is an urgent need for a better understanding of the effects of globalization on the full food system and its externalities. The yield gap is not static. Maintaining, let alone increasing, productivity depends on continued innovation to control weeds, diseases, insects, and other pests as they evolve resistance to different control measures, or as new species emerge or are dispersed to new regions. Innovation involves both traditional and advanced crop and livestock breeding, as well as the continuing development of better chemical, agronomic, and agro-ecological control measures. The maximum attainable yield in different regions will also shift as the effects of climate change are felt. Increasing atmospheric CO₂ levels can directly stimulate crop growth, though within the context of real
agricultural production systems, the magnitude of this effect is not clear (7). More important will be the ability to grow crops in places that are currently unsuitable, particularly the northern temperate regions (though expansion of agriculture at the expense of boreal forest would lead to major greenhouse gas emissions), and the loss of currently productive regions because of excessively high temperatures and drought. Models that couple the physics of climate change with the biology of crop growth will be important to help policy-makers anticipate these changes, as well as to evaluate the role of “agricultural biodiversity” in helping mitigate their effects (25).

Closing the yield gap would dramatically increase the supply of food, but with uncertain impacts on the environment and potential feedbacks that could undermine future food production. Food production has important negative “externalities,” namely effects on the environment or economy that are not reflected in the cost of food. These include the release of greenhouse gases (especially methane and nitrous oxide, which are more damaging than CO₂ and for which agriculture is a major source (26)), environmental pollution due to nutrient run-off, water shortages due to overextraction, soil degradation and the loss of biodiversity through land conversion or inappropriate management, and ecosystem disruption due to the intensive harvesting of fish and other aquatic foods (6).

To address these negative effects, it is now widely recognized that food production systems and the food chain in general must become fully sustainable (18). The principle of sustainability implies the use of resources at rates that do not exceed the capacity of Earth to replace them. By definition, dependency on nonrenewable inputs is unsustainable, even if in the short term it is necessary as part of a trajectory toward sustainability.

There are many difficulties in making sustainability operational. Over what spatial scale should food production be sustainable? Clearly an overarching goal is global sustainability, but should this goal also apply at lower levels, such as regions (or oceans), nations, or farms? Could high levels of consumption or negative externalities in some regions be mitigated by improvements in other areas, or could some unsustainable activities in the food system be offset by actions in the nonfood sector (through carbon-trading, for example)? Though simple definitions of sustainability are independent of time scale, in practice, how fast should we seek to move from the status quo to a sustainable food system? The challenges of climate change and competition for water, fossil fuels, and other resources suggest that a rapid transition is essential. Nevertheless, it is also legitimate to explore the possibility that superior technologies may become available and that future generations may be wealthier and, hence, better able to absorb the costs of the transition. Finally, we do not yet have good enough metrics of sustainability, a major problem when evaluating alternative strategies and negotiating trade-offs. This is the case for relatively circumscribed activities, such as crop production on individual farms, and even harder when the complete food chain is included or for complex products that may contain ingredients sourced from all around the globe. There is also a danger that an overemphasis on what can be measured relatively simply (carbon, for example) may lead to dimensions of sustainability that are harder to quantify (such as biodiversity) being ignored. These are areas at the interface of science, engineering, and economics that urgently need more attention (see Box 1). The introduction of measures to promote sustainability does not necessarily reduce yields or profits. One study of 286 agricultural sustainability projects in developing countries, involving 12.6 million chiefly small-holder farmers on 37 million hectares, found an average yield increase of 79% across a very wide variety of systems and crop types (27). One-quarter of the projects reported a doubling of yield. Research on the ability of these and related programs to be scaled up to country and regional levels should be a priority (Fig. 2).

Fig. 2. An example of a major successful sustainable agriculture project. Niger was strongly affected by a series of drought years in the 1970s and 1980s and by environmental degradation. From the early 1980s, donors invested substantially in soil and water conservation. The total area treated is on the order of 300,000 ha, most of which went into the rehabilitation of degraded land. The project in the Illélé district of Niger promoted simple water-harvesting techniques. Contour stone bunds, half moons, stone bunding, and improved traditional planting pits (“zaï”) were used to rehabilitate barren, eroded land. More than 300,000 ha have been rehabilitated, and crop yields have increased and become more stable from year to year. Tree cover has increased, as shown in the photographs. Development of the land market and continued incremental expansion of the treated area without further project assistance indicate that the outcomes are sustainable (51, 52).

...
TABLE 1. Examples of current and potential future applications of GM technology for crop genetic improvement. [Source: (28, 49)]

<table>
<thead>
<tr>
<th>Time scale</th>
<th>Target crop trait</th>
<th>Target crops</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current</td>
<td>Tolerance to broad-spectrum herbicide</td>
<td>Maize, soybean, oilseed brassica</td>
</tr>
<tr>
<td></td>
<td>Resistance to chewing insect pests</td>
<td>Maize, cotton, oilseed brassica</td>
</tr>
<tr>
<td>Short-term</td>
<td>Nutritional bio-fortification</td>
<td>Staple cereal crops, sweet potato</td>
</tr>
<tr>
<td>(5–10 years)</td>
<td>Resistance to fungus and virus pathogens</td>
<td>Potato, wheat, rice, banana, fruits, vegetables</td>
</tr>
<tr>
<td></td>
<td>Resistance to sucking insect pests</td>
<td>Rice, fruits, vegetables</td>
</tr>
<tr>
<td></td>
<td>Improved processing and storage</td>
<td>Wheat, potato, fruits, vegetables</td>
</tr>
<tr>
<td>Medium-term</td>
<td>Drought tolerance</td>
<td>Staple cereal and tuber crops</td>
</tr>
<tr>
<td>(10–20 years)</td>
<td>Salinity tolerance</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Increased nitrogen-use efficiency</td>
<td>Staple cereal and tuber crops</td>
</tr>
<tr>
<td>Long-term</td>
<td>High-temperature tolerance</td>
<td>Staple cereal and tuber crops</td>
</tr>
<tr>
<td>(&gt;20 years)</td>
<td>Aporphix</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Nitrogen fixation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Denitrification inhibitor</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Conversion to perennial habit</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Increased photosynthetic efficiency</td>
<td></td>
</tr>
</tbody>
</table>

Agricultural land in developing countries. This external investment in developing-country agriculture may bring major benefits, especially where investors bring considerable improvements to crop production and processing, but only if the rights and welfare of the tenants and existing resource users are properly addressed (31).

Many of the very poorest people live in areas so remote that they are effectively disconnected from national and world food markets. But for others, especially the urban poor, higher food prices have a direct negative effect on their ability to purchase a healthy diet. Many rural farmers and other food producers live near the margin of being net food consumers and producers and will be affected in complex ways by rising food prices, with some benefitting and some being harmed (27). Thus, whereas reducing distorting agricultural support mechanisms in developed countries and liberalizing world trade should stimulate overall food production in developing countries, not everyone will gain (23, 32). Better models that can more accurately predict these complex interactions are urgently needed.

Increasing production limits

The most productive crops, such as sugar cane, growing in optimum conditions, can convert solar energy into biomass with an efficiency of ~2%, resulting in high yields of biomass (up to 150 metric tons per hectare) (33). There is much debate over exactly what the theoretical limits are for the major crops under different conditions, and similarly, for the maximum yield that can be obtained for livestock rearing (18). However, there is clearly considerable scope for increasing production limits.

The Green Revolution succeeded by using conventional breeding to develop F1 hybrid varieties of maize and semi-dwarf, disease-resistant varieties of wheat and rice. These varieties could be provided with more irrigation and fertilizer (20) without the risk of major crop losses due to lodging (falling over) or severe rust epidemics. Increased yield is still a major goal, but the importance of greater water- and nutrient-use efficiency, as well as tolerance of abiotic stress, is also likely to increase. Modern genetic techniques and a better understanding of crop physiology allow for a more directed approach to selection across multiple traits. The speed and costs at which genomes today can be sequenced or resequenced now means that these techniques can be more easily applied to develop varieties of crop species that will yield well in challenging environments. These include crops such as sorghum, millet, cassava, and banana, species that are staple foods for many of the world’s poorest communities (34).

Currently, the major commercialized genetically modified (GM) crops involve relatively simple manipulations, such as the insertion of a gene for herbicide resistance or another for a pest-insect toxin. The next decade will see the development of combinations of desirable traits and the introduction of new traits such as drought tolerance. By mid-century, much more radical options involving highly polygenic traits may be feasible (Table 1). Production of cloned animals with engineered innate immunity to diseases that reduce production efficiency has the potential to reduce substantial losses arising from mortality and subclinical infections. Biotechnology could also produce plants for animal feed with modified composition that increase the efficiency of meat production and lower methane emissions.

Domestication inevitably means that only a subset of the genes available in the wild species progenitor gene pool is represented among crop varieties and livestock breeds. Unexploited genetic material from land races, rare breeds, and wild relatives will be important in allowing breeders to respond to new challenges. International collections and gene banks provide valuable repositories for such genetic variation, but it is nevertheless necessary to ensure that locally adapted crop and livestock germplasm is not lost in the process of their displacement by modern, improved varieties and breeds. The trend over recent decades is of a general decline in investment in technological innovation in food production (with some notable exceptions, such as in China and Brazil) and a switch from public to private sources (1). Fair returns on investment are essential for the proper functioning of the private sector, but the extension of the protection of intellectual property rights to biotechnology has led to a growing public perception in some countries that biotech research purely benefits commercial interests and offers no long-term public good. Just as seriously, it also led to a virtual monopoly of GM traits in some parts of the world, by a restricted number of companies, which limits innovation and investment in the technology. Finding ways to incentivize wide access and sustainability, while encouraging a competitive and innovative private sector to make best use of developing technology, is a major governance challenge.

The issue of trust and public acceptance of biotechnology has been highlighted by the debate over the acceptance of GM technologies. Because genetic modification involves germline modification of an organism and its introduction to the environment and food chain, a number of particular environmental and food safety issues need to be assessed. Despite the introduction of rigorous science-based risk assessment, this discussion has become highly politicized and polarized in some countries, particularly those in Europe. Our view is that genetic modification is a potentially valuable technology whose advantages and disadvantages need to be considered rigorously on an evidential, inclusive, case-by-case basis: Genetic modification should neither be privileged nor automatically dismissed. We also accept the need for this technology to gain greater public acceptance and trust before it can be considered as one among a set of technologies that may contribute to improved global food security.

There are particular issues involving new
technologies, both GM and non-GM, that are targeted at helping the least-developed countries (35, 36). The technologies must be directed at the needs of those communities, which are often different from those of more developed country farmers. To increase the likelihood that new technology works for, and is adopted by, the poorest nations, they need to be involved in the framing, prioritization, risk assessment, and regulation of innovations. This will often require the creation of innovative institutional and governance mechanisms that account for socio-cultural context (for example, the importance of women in developing-country food production). New technologies offer major promise, but there are risks of lost trust if their potential benefits are exaggerated in public debate. Efforts to increase sustainable production limits that benefit the poorest nations will need to be based around new alliances of businesses, civil society organizations, and governments.

Reducing waste

Roughly 30 to 40% of food in both the developed and developing worlds is lost to waste, though the causes behind this are very different (Fig. 3) (16, 37–39). In the developing world, losses are mainly attributable to the absence of food-chain infrastructure and the lack of knowledge or investment in storage technologies on the farm, although data are scarce. For example, in India, it is estimated that 35 to 40% of fresh produce is lost because neither wholesale nor retail outlets have cold storage (36). Even with rice grain, which can be stored more readily, as much as one-third of the harvest in Southeast Asia can be lost after harvest to pests and spoilage (40). But the picture is more complex than a simple lack of storage facilities: Although storage after harvest when there is a glut of food would seem to make economic sense, the farmer often has to sell immediately to raise cash.

In contrast, in the developed world, pre-retail losses are much lower, but those arising at the retail, food service, and home stages of the food chain have grown dramatically in recent years, for a variety of reasons (41). At present, food is relatively cheap, at least for these consumers, which reduces the incentives to avoid waste. Consumers have become accustomed to purchasing foods of the highest cosmetic standards; hence, retailers discard many edible, yet only slightly blemished products. Commercial pressures can encourage waste: The food service industry frequently uses “super-sized” portions as a competitive lever, whereas “buy one get one free” offers have the same function for retailers. Litigation and lack of education on food safety have lead to a reliance on “use by” dates, whose safety margins often mean that food fit for consumption is thrown away. In some developed countries, unwanted food goes to a landfill instead of being used as animal feed or compost because of legislation to control prion diseases.

Different strategies are required to tackle the two types of waste. In developing countries, public investment in transport infrastructure would reduce the opportunities for spoilage, whereas better-functioning markets and the availability of capital would increase the efficiency of the food chain, for example, by allowing the introduction of cold storage (though this has implications for greenhouse gas emissions) (38). Existing technologies and best practices need to be spread by education and extension services, and market and finance mechanisms are required to protect farmers from having to sell at peak supply, leading to gluts and wastage. There is also a need for continuing research in postharvest storage technologies. Improved technology for small-scale food storage in poorer contexts is a prime candidate for the introduction of state incentives for private innovation, with the involvement of small-scale traders, millers, and producers.

If food prices were to rise again, it is likely that there would be a decrease in the volume of waste produced by consumers in developed countries. Waste may also be reduced by alerting consumers to the scale of the issue, as well as to domestic strategies for reducing food loss. Advocacy, education, and possibly legislation may also reduce waste in the food service and retail sectors. Legislation such as that on sell-by dates and swill that has inadvertently increased food waste should be reexamined within a more inclusive competing-risks framework. Reducing developed-country food waste is particularly challenging, as it is so closely linked to individual behavior and cultural attitudes toward food.

Changing diets

The conversion efficiency of plant into animal matter is ~10%; thus, there is a prima facie case that more people could be supported from the same amount of land if they were vegetarians. About one-third of global cereal production is fed to animals (42). But currently, one of the major challenges to the food system is the rapidly increasing demand for meat and dairy products that has led, over the past 50 years, to a ~1.5-fold increase in the global numbers of cattle, sheep, and goats, with equivalent increases of ~2.5- and ~4.5-fold for pigs and chickens, respectively (2) (Fig. 1). This is largely attributable to the increased wealth of consumers everywhere and most recently in countries such as China and India.

However, the argument that all meat consumption is bad is overly simplistic. First, there is substantial variation in the production efficiency and environmental impact of the major classes of meat consumed by people (Table 2). Second, although a substantial fraction of livestock is fed on grain and other plant protein that could feed humans, there remains a very substantial proportion that is grass-fed. Much of the grassland that is used to feed these animals could not be converted to arable land or could only be converted with majorly adverse environmental outcomes. In addition, pigs and poultry are often fed on human food “waste.” Third, through better rearing or improved breeds, it may be possible to increase the efficiency with which meat is produced. Finally, in developing countries, meat represents the most concentrated source of some vitamins and minerals, which is important for individuals such as young children. Livestock also are used for ploughing and transport, provide a local supply of manure, can be a vital source of income, and are of huge cultural importance for many poorer communities.

Reducing the consumption of meat and increasing the proportion that is derived from the most efficient sources offer an opportunity to feed more people and also present other advantages (37). Well-balanced diets rich in grains and other vegetable products are considered to be more healthful than those containing a high proportion of meat (especially red meat) and dairy products. As developing countries consume more meat in combination with high-sugar and -fat foods, they may find themselves having to deal with obesity before they have overcome undernutrition, leading to an increase in spending on health that could otherwise be used to alleviate poverty. Livestock production is also a major source
Comparison of the impact of grazing and intensive (confined/industrialized) grain-fed livestock systems on water use, grain requirement, and methane production. Service water is that required for cleaning and washing livestock housing and other facilities. Dashes indicate combinations for which no data are available (either because it cannot be measured or because the combination does not exist). This table does not include other impacts of differing livestock management systems such as (i) nutrient run-off and pollution to surface and groundwater, (ii) protozoan and bacterial contamination of water and food, (iii) antibiotic residues in water and food, (iv) heavy metal from feed in soils and water, (v) odor nuisance from wastes, (vi) inputs used for feed production and lost to the environment, (vii) livestock-related land-use change. [Source: (7.50)]

<table>
<thead>
<tr>
<th>Water</th>
<th>Measure of water use</th>
<th>Grazing</th>
<th>Intensive</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Liters day⁻¹ per animal at 15°C</td>
<td></td>
</tr>
<tr>
<td>Cattle</td>
<td>Drinking water: all</td>
<td>22</td>
<td>103</td>
</tr>
<tr>
<td></td>
<td>Service water: beef</td>
<td>5</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Service water: dairy</td>
<td>5</td>
<td>22</td>
</tr>
<tr>
<td>Pigs (lactating adult)</td>
<td>Drinking water</td>
<td>17</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>Service water</td>
<td>25</td>
<td>125</td>
</tr>
<tr>
<td>Sheep (lactating adult)</td>
<td>Drinking water</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Service water</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Chicken (broiler and layer)</td>
<td>Drinking water</td>
<td>1.3–1.8</td>
<td>1.3–1.8</td>
</tr>
<tr>
<td></td>
<td>Service water</td>
<td>0.09–0.15</td>
<td>0.09–0.15</td>
</tr>
<tr>
<td>Feed required to produce 1 kg of meat</td>
<td>kg of cereal per animal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cattle</td>
<td></td>
<td>–</td>
<td>8</td>
</tr>
<tr>
<td>Pigs</td>
<td></td>
<td>–</td>
<td>4</td>
</tr>
<tr>
<td>Chicken (broiler)</td>
<td></td>
<td>–</td>
<td>1</td>
</tr>
</tbody>
</table>

Methane emissions from cattle | kg of CH₄ per animal year⁻¹ |
Cattle: dairy (U.S., Europe) | – | 117–128 |
Cattle: beef, dairy (U.S., Europe) | 53–60 | – |
Cattle: dairy (Africa, India) | – | 45–58 |
Cattle: grazing (Africa, India) | 27–31 | – |

of methane, a very powerful greenhouse gas, though this can be partially offset by the use of animal manure to replace synthetic nitrogen fertilizer (43). Of the five strategies we discuss here, assessing the value of decreasing the fraction of meat in our diets is the most difficult and needs to be better understood.

Expanding aquaculture

Aquatic products (mainly fish, aquatic molluscs, and crustaceans) have a critical role in the food system, providing nearly 3 billion people with at least 15% of their animal protein intake (44).

In many regions, aquaculture has been sufficiently profitable to permit strong growth; replicating this growth in areas such as Africa where it has not occurred could bring major benefits. Technical advances in hatchery systems, feeds and feed-delivery systems, and disease management could all increase output. Future gains may also come from better stock selection, larger-scale production technologies, aquaculture in open seas and larger inland water bodies, and the culture of a wider range of species. The long production cycle of many species (typically 6 to 24 months) requires a financing system that is capable of providing working capital as well as offsetting risk. Wider production options (such as temperature and salinity tolerance and disease resistance) and cheaper feed substrates (for instance, plant material with enhanced nutritional features) might also be accessed with the use of GM technologies.

Aquaculture may cause harm to the environment because of the release into water bodies of organic effluents or disease treatment chemicals, indirectly through its dependence on industrial fisheries to supply feeds, and by acting as a source of diseases or genetic contamination for wild species. Efforts to reduce these negative externalities and increase the efficiency of resource use (such as the fish in–to–fish out ratio (45)) have been spurred by the rise of sustainability certification programs, though these mainly affect only higher-value sectors. Gains in sustainability could come from concentrating on lower–trophic level species and in integrating aquatic and terrestrial food production, for example, by using waste from the land as food and nutrients. It will also be important to take a more strategic approach to site location and capacity within catchment or coastal zone management units (46).

Conclusions

There is no simple solution to sustainably feeding 9 billion people, especially as many become increasingly better off and converge on rich-country consumption patterns. A broad range of options, including those we have discussed here, needs to be pursued simultaneously. We are hopeful about scientific and technological innovation in the food system, but not as an excuse to delay difficult decisions today.

Any optimism must be tempered by the enormous challenges of making food production sustainable while controlling greenhouse gas emission and conserving dwindling water supplies, as well as meeting the Millennium Development Goal of ending hunger. Moreover, we must avoid the temptation to further sacrifice Earth’s already hugely depleted biodiversity for easy gains in food production, not only because biodiversity provides many of the public goods on which mankind relies but also because we do not have the right to deprive future generations of its economic and cultural benefits. Together, these challenges amount to a perfect storm.

Navigating the storm will require a revolution in the social and natural sciences concerned with food production, as well as a breaking down of barriers between fields. The goal is no longer simply to maximize productivity, but to optimize across a far more complex landscape of production, environmental, and social justice outcomes.

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53. The authors are members of the U.K. Government Office for Science’s Foresight Project on Global Food and Farming Futures. J.R.B. is also affiliated with Imperial College London. D.L. is a Board Member of Plastid AS (Norway) and owns shares in AstraZeneca Public Limited Company and Syngenta AG. We are grateful to J. Krebs and J. Ingrahm (Oxford), N. Nisbett and D. Flynn (Foresight), and colleagues in Defra and DfID for their helpful comments on earlier drafts of this manuscript. If not for his sad death in July 2009, Mike Gale (John Innes Institute, Norwich, UK) would also have been an author of this paper.

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The global economic burden of malnutrition

Tomas J. Philipson¹, Mark T. Linthicum², and Julia Thornton Snider²*

A round the world, malnutrition imposes an immense burden on society through its effects on health as well as its economic impacts. Whether malnutrition arises due to poverty or is associated with disease, cost-effective interventions are available to reduce this burden. Existing evidence suggests that the benefits of such efforts are likely to exceed the costs. In this article, we review and summarize the burden on society from malnutrition and discuss cost-effective solutions.

Introduction

According to 2009 data from the Food and Agriculture Organization of the United Nations, 1.02 billion people globally, or approximately one in six individuals, are undernourished (1). Malnutrition has deleterious health consequences at both the individual and societal level. Functionally, malnutrition¹ negatively affects almost every system in the body, and is associated with stunted growth (2, 3), reduced muscle strength and endurance (4), diminished gut function (5), impaired cognition across the lifespan (6, 7), and compromised immune function (5, 8).

In developing regions, malnutrition has stemmed primarily from poverty leading to inadequate food intake (2). But in developed countries, the prevalence of malnutrition associated with noncommunicable or chronic disease (for example cancer or heart disease) has risen considerably (9, 10). At the societal level, malnutrition imposes a substantial burden in morbidity, mortality, and economic costs (see Figure 1) (1, 11).

In this article, we summarize the burden of malnutrition in developing and developed countries, comment on how malnutrition differs in the two settings, and discuss cost-effective solutions. We find that the burden of malnutrition is large in both settings, though for different reasons. Yet a multitude of interventions, such as malnutrition screening, micronutrient supplementation, and provision of oral nutritional supplements, can be used to reduce the burden of malnutrition in a cost-effective manner.

Malnutrition in developing countries

While the effects of poverty on health and nutrition impact people in every country, poverty-related malnutrition is particularly prevalent in low-income countries. Populations in extreme poverty are vulnerable to economic or environmental shocks, such as prolonged drought or civil conflict, leaving them at risk of starvation. While such crises of acute and widespread hunger may be more visible, chronic malnutrition also imposes a substantial burden on these countries and society in general (3, 11–13).

The effects of poverty-related malnutrition are most widespread and serious among children and maternal-age women (3, 11–13). A recent study estimates that 3.1 million child deaths per year are caused, at least in part, by undernutrition (12).

In addition to the considerable burden from increased morbidity, chronic childhood undernutrition leads to stunting, delayed intellectual development, and other problems that have lifelong impacts. Approximately one in three children in developing nations is underweight or stunted, and micronutrient deficiencies affect approximately 30% of people in these countries (11). Moreover, childhood undernutrition is linked to lower educational attainment and lower economic productivity as an adult (2, 13). Over a lifetime, undernutrition reduces lifetime earnings by more than 10% (11).

Given the far-reaching health and economic effects of poverty-related undernutrition, it is perhaps not surprising that programs to reduce undernutrition in the developing world have been found to be among the most cost-effective development programs (14, 15). Micronutrient supplementation, for example, is a well-documented approach to battling the effects of undernutrition. Considerable research has been devoted to determining the efficacy and cost-effectiveness of supplementation/fortification programs addressing iodine and vitamin A deficiency, with ongoing work under way to identify the best way to deliver iron, folate, and zinc (16). To work most effectively, these programs are ideally incorporated alongside screening approaches and nutrition education provided either at the community or primary care level, with a particular emphasis on the needs of gestating and lactating women, and early childhood (16, 17).

Poverty-related undernutrition is particularly prevalent in regions of Africa and South and central Asia, where many low-income countries are concentrated. As economies develop, the prevalence of poverty-related undernutrition tends to diminish. For example, the prevalence of underweight children in China fell by nearly 82% between 1987 and 2010 (18), which coincided with a period of rapid economic growth. However, the prevalence of chronic noncommunicable

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It should be noted that, although the focus of this paper is on undernutrition due to poverty or disease, overnutrition also has significant negative health consequences (e.g., diabetes and cardiovascular disease), and the overweight and obese may also be malnourished.
diseases has increased in tandem with economic growth, leading to an accompanying increase in disease-associated malnutrition (DAM), discussed below.

**Malnutrition in emerging and developed countries**

Relative to hunger-related malnutrition, DAM is more prevalent in industrialized nations, where malnutrition is more likely to stem from disease-related processes. DAM has multiple precipitants, including reduced dietary intake (for example, due to appetite loss or dysphagia), macro- or micronutrient malabsorption (a particular risk for patients with intestinal conditions), and increased nutritional needs triggered by illness. DAM is disproportionately prevalent in elderly individuals and those with chronic disease (19–21), affecting approximately 10% of chronically ill individuals and 30%–50% of hospitalized patients in the U.S. (22–25).

From an economic perspective, DAM imposes a substantial burden on society by increasing morbidity, mortality, disability, and treatment costs. A recent study estimated the total annual economic burden of malnutrition associated with eight diseases in the U.S. to be US$167.4 billion (in 2013 dollars), or $543 per U.S. resident (21). A disproportionate share of this burden—33% or $54.8 billion—fell on the elderly, who make up only 13% of the U.S. population (21). [Further calculation using the study model reveals a breakdown of 7% of the burden among the elderly from direct medical spending, 69% from excess morbidity (21), and 24% from excess mortality.] A comparable study in Europe that included malnutrition associated with 10 separate diseases, estimated the health and financial burden to be US$443.4 billion (in 2013 dollars), or US$531 per European resident (26).

The burden of DAM is not limited to historically wealthy nations, however. As the economies of countries such as China and Brazil transition to greater levels of industrialization, public health issues increasingly shift from communicable disease and poverty-related undernutrition to noncommunicable chronic disease and accompanying DAM (27–29). Recent research on DAM associated with 15 diseases in China indicates an annual burden from increased morbidity and mortality of 6.1 million disability-adjusted life years (DALYs) lost. Applying economic valuation methods similar to those used in studies of DAM in the U.S., this amounts to an...
annual economic burden of US$948 billion (in 2013 dollars), which exceeds the burden in the U.S. and Europe combined (30). As in the U.S., the elderly bear a disproportionate share of the burden from DAM: 13.4% of the Chinese population is ≥60 years old, but this group bears 38.0% of the burden.

Interventions aimed at reducing malnutrition

The substantial economic burden from DAM makes it an important policy priority. Fortunately, effective and relatively inexpensive interventions are available to reduce this condition and improve patient outcomes (16, 31–34).

In order to treat DAM, providers must first know which patients are malnourished. Although screening for nutritional status has been found to be a cost-effective strategy (23), and is recommended by the Joint Commission for the Accreditation of Health Care Organizations, research indicates that many patients may never be screened (35) and up to 50% of malnourished individuals are never identified (22).

Once DAM has been identified, low-cost options exist to improve nutritional status and energy balance. For example, in-hospital dieticians and physicians may counsel patients with specific micronutrient deficiencies on a healthier diet plan or provide supplementation of their existing diet. Oral nutritional supplements (ONS) are food and fluids modified to deliver protein, carbohydrate, lipid, and/or micronutrient fortification and are typically used when normal dietary intake is insufficient to meet daily nutritional requirements (36, 37). ONS are most commonly provided to patients when they interact with the health care sector, with their use potentially continuing in the community setting (38).

A substantial amount of research has been conducted in the U.S. and Europe over the past decade to evaluate the impact of nutrition screening and ONS provision in adult and elderly DAM patients in various settings. Specifically, both during and after hospitalization for a range of medical, pre-surgical, and post-surgical conditions, patients who received nutritional screening and ONS showed consistent improvements in quality of life and physiologic markers, alongside decreased readmissions and reduced complication rates (33, 34, 39–41).

The available literature on the effectiveness of ONS in addressing DAM in clinical settings is largely confined to industrialized nations in the U.S. and Europe, indicating a need for more research in developing countries. However, available data indicate a consistent and positive impact of ONS, both clinically and financially, across a range of study types including randomized controlled trials, meta-analyses, and observational and economic analyses (33, 34, 39–42).

Research across developing and developed regions shows that the implementation of nutrition screening and support protocols in clinical or institutional settings provides a low-cost way to identify and treat individuals who will benefit from nutrition intervention (17, 22, 23, 33, 34, 39–44). The recent move by the U.S. Centers for Medicare and Medicaid Services to increase the freedom of registered dieticians to manage patients’ diets and order nutrition-related laboratory tests reflects the strength of the evidence that the potential benefits of nutrition interventions are likely to far exceed their costs (45).

Conclusions

Malnutrition imposes a significant health and economic burden through increased morbidity and mortality, impaired physical and intellectual development of children, decreased economic productivity, and increased costs of health care. In developing countries, the primary trigger of malnutrition continues to be poverty, with children and maternal-age women most at-risk of long-term detriment (11–13). In the developed world, the bulk of the societal burden from malnutrition is due to DAM and is borne disproportionately by the elderly. In reality, both resource-related malnutrition and DAM exist in all countries. This is particularly true in a large number of middle-income countries, such as China, India, and Brazil. In these cases, both disease and poverty are likely to be major drivers of malnutrition, and strategies to reduce malnutrition must consider both. As the elderly are expected to live longer, population susceptibility to chronic diseases is increased and the impact of DAM on society is likely to increase. As such, it is important for policymakers and medical professionals in developed and middle income countries to understand the size of the burden from DAM as well as strategies to reduce the burden.

Current evidence suggests that cost-effective strategies exist to reduce the burden from both poverty- and disease-associated malnutrition. Addressing poverty-related malnutrition through micronutrient supplements and micronutrient fortification has been identified as two of the best ways to advance global welfare (14, 15). In the realm of DAM, a powerful case can be made for the importance of identifying patients at high risk and targeting additional resources to improve nutrition management in clinical settings. Compared with many interventions commonly used to address complex conditions, nutrition interventions are often cost saving or at minimum highly cost-effective, and may lead to improvements in underlying disease states. In addition, the societal value of potential longevity gains, morbidity and mortality reductions, and increased economic productivity accompanying effective nutrition management are high. This makes reducing malnutrition not only an important clinical and public health issue, but also an attractive economic target. Given the large burden imposed by malnutrition, and the availability of cost-effective solutions, this problem deserves to be a global policy priority.

References

China’s demographic history and future challenges

Xizhe Peng

On 28 April 2011, China’s state statistics bureau released its first report on the country’s 2010 population census. The report states that the total population of mainland China reached 1.3397 billion in 2010, with an annual average population growth rate of 0.57% during the previous 10 years. The share of the total population aged 0 to 14 declined from 22.9% in 2000 to 16.6% in 2010, whereas the proportion aged 65 and above grew from 7.0% to 8.9% during the same period. This indicates that China’s population is aging rapidly. The report also shows that China is urbanizing, with nearly half of the population—665.57 million people, or 49.7%—living in urban areas, an increase of 13 percentage points over the 2000 figure. Moreover, about 260 million Chinese people are living away from where they are formally registered, and the overwhelming majority of them (about 220 million) are rural migrants living and working in urban areas but without formal urban household registration status. China is at a demographic turning point: It is changing from an agricultural society into an urban one, from a young society to an old one, and from a society attached to the land to one that is very much on the move.

There was considerable uncertainty about the size of China’s population before 1953, when the country held its first national census of modern times. The population enumerated by the 1953 census, 594.4 million, revealed rapid population growth at a very high rate. China then conducted a partial census in 1964 and a complete one in 1982 with support from the United Nations Population Fund (UNFPA). China has since carried out censuses in 1990, 2000, and 2010 (Table 1). Although the national population census is the most reliable source of demographic data, the household registration system and other survey data collected by various government agencies and academic institutions also provide information of varied coverage and quality. However, there are widespread concerns in the scientific community regarding the quality of some of these population data. An example is the current controversy as to the level of fertility in the country and its regions. Users of Chinese population data should bear these concerns in mind.

Review of the past and current demographic situation

The current demographic situation in China reflects the profound demographic transition of the past several decades. Both mortality and fertility have declined substantially.

The country’s crude death rate fell from about 25 deaths per thousand per year in the early 1950s to about 7 per thousand today; life expectancy at birth has almost doubled, from 40 years to around 73 years [see (4) for a discussion of mortality during the early years of the PRC]. The period 1959–1961 witnessed an exceptional demographic fluctuation mainly attributable to the great famine, with more than 20 million excess deaths and the postponement of 20 million births (5). China’s most substantial mortality decrease took place in the period between 1950 and 1975, when the country was still one of the poorest in the world. This rapid decline of the death rate is mainly a result of economic development and improvements in education and health services, especially the public hygiene movement that resulted in a sharp drop in mortality from infectious diseases (6). Rapid mortality decline was recorded first among children and young adults and then spread to middle- and old-age groups (7). The infant mortality rate has declined from 203 per thousand births in 1949 to 14 in 2010. Mortality decline has continued throughout the period of China’s economic reform since the late 1970s, although at a slower pace. Cardiovascular disease, cancers, and respiratory and digestive diseases are now the leading causes of death, and the situation is quite similar to that of developed countries (8).

High fertility and declining mortality dominated China’s demographic profile before the early 1970s. As a consequence, the first two decades of the PRC (1950 to 1970) were a time of rapid population growth, with an average annual growth rate of above 2%. Fertility decline emerged first in the country’s urban areas in the mid-1960s and is attributed partly to the increased availability of contraceptive services provided to urban residents. However, the country’s nationwide fertility transition dates from the early 1970s and was initiated by the government-sponsored family planning program. The total fertility rate (TFR) declined sharply from about 5.8 births per woman in 1970 to 2.8 births in 1979, a decrease of more than 50%. The TFR dropped to below the replacement level in the early 1990s and is now thought to be around 1.5 births per woman.

There is no doubt that government commitment, and the efficient and sometimes coercive implementation of the family planning program, were the major determinants of China’s rapid fertility decline. No numerical birth-control target was set when China began its nationwide family planning program in the 1970s. Instead, the program of the 1970s emphasized late marriage and childbearing, longer interbirth intervals, and therefore fewer children. The so-called “one-child policy” was introduced in the late 1970s—after most of the fertility decline had occurred, and partially as a response to China’s ambitious stride toward

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<tr>
<td>Population (millions)</td>
<td>594.4</td>
<td>694.6</td>
<td>1008.2</td>
<td>1133.7</td>
<td>1265.8</td>
<td>1334</td>
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<td>Birth rate (per 1000)</td>
<td>37.0</td>
<td>39.3</td>
<td>22.3</td>
<td>21.1</td>
<td>14.0</td>
<td>12.6</td>
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<td>Death rate (per 1000)</td>
<td>14.0</td>
<td>11.6</td>
<td>6.6</td>
<td>6.7</td>
<td>6.5</td>
<td>7.1</td>
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<td>Natural increase (per 1000)</td>
<td>23.0</td>
<td>27.8</td>
<td>15.7</td>
<td>14.4</td>
<td>7.6</td>
<td>5.5</td>
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<td>Family household size</td>
<td>4.3</td>
<td>4.4</td>
<td>4.4</td>
<td>4.0</td>
<td>3.4</td>
<td>3.1</td>
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<tr>
<td>Percent aged 65+</td>
<td>4.4</td>
<td>3.6</td>
<td>4.9</td>
<td>5.6</td>
<td>7.0</td>
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<td>Percent aged 0 to 14</td>
<td>36</td>
<td>39.9</td>
<td>33.6</td>
<td>27.7</td>
<td>22.9</td>
<td>16.6</td>
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<td>Total fertility rate</td>
<td>5.8</td>
<td>5.8</td>
<td>2.6</td>
<td>2.3</td>
<td>1.7</td>
<td>1.5†</td>
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<tr>
<td>Female life expectancy</td>
<td>—</td>
<td>—</td>
<td>69.3</td>
<td>70.5</td>
<td>73.3</td>
<td>76†</td>
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<td>Male life expectancy</td>
<td>—</td>
<td>—</td>
<td>66.3</td>
<td>68.8</td>
<td>69.6</td>
<td>72†</td>
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<td>Infant mortality rate</td>
<td>138.5</td>
<td>84.3</td>
<td>34.7</td>
<td>32.9</td>
<td>28.9</td>
<td>13.8</td>
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<td>Sex ratio at birth (female = 100)</td>
<td>104.88</td>
<td>103.86</td>
<td>108.47</td>
<td>111.3</td>
<td>116.86</td>
<td>118.06</td>
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<td>Illiteracy rate</td>
<td>—</td>
<td>33.6</td>
<td>22.8</td>
<td>15.9</td>
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<tr>
<td>Percent urban</td>
<td>13.0</td>
<td>18.3</td>
<td>20.9</td>
<td>26.4</td>
<td>36.2</td>
<td>49.7</td>
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<td>Per capita GDP (RMB yuan)</td>
<td>—</td>
<td>528</td>
<td>1644</td>
<td>7858</td>
<td>25575†</td>
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For 1964, this refers to the population aged 13 and over who are unable to read; for 1982, 1990, 2000, and 2010, this refers to the population aged 15 and over who are unable to read or have difficulty reading. †Figures for 2009. ‡Estimated.
modernization—and its implementation relied heavily on government administrative systems with financial and other incentive and disincentive measures. In fact, China has never implemented a pure one-child policy. In general, a strict “one-child policy” has only been carried out among urban residents. The majority of the rural families are allowed to have two children, whereas regulations for minority ethnic populations are more flexible (9). Therefore, the term “one-child policy” is an oversimplification. It is also evident that other social and economic factors, such as advances in education, improvements in the position of women, and reductions in mortality, also contributed to the general fertility decline.

There has always been marked regional variation in all demographic indicators in China. Thus, TFRs today range from above 2.2 births per woman in some of the inland provinces to well below 1 in the major cities of Shanghai and Beijing (Table 2). Similar variation exists with respect to life expectancy: The highest, 79 years, is recorded in Shanghai; the lowest, about 69 years, is reported for Yunnan and Qinghai provinces and Xizang (Tibet) autonomous region. Urbanization and population aging show similar regional patterns. Thus, the more socioeconomically advanced regions of the country tend to be much more urbanized and to have older populations.

The level of urbanization in China before the 1980s was quite low, and it increased very slowly over time. Indeed, the country was widely viewed as an example of “underurbanization”—that is, a case of industrial growth without parallel urbanization. Only about 20% of the population lived in urban areas in the late 1970s. However, the urbanization process has accelerated since the beginning of China’s economic reforms in the early 1980s. Today about half of the population lives in the country’s 655 cities and more than 20,000 towns. Between 2000 and 2010,
the urban areas absorbed more than 15 million newcomers each year. People are increasingly concentrated in relatively small geographic regions, particularly in city belts such as those of the Yangtze River and Pearl River deltas and the Beijing-Tianjin region. The urbanization process during the reform era follows a worldwide trend of an increasing share of the population residing in cities. However, it also has a distinctive trait that challenges how we understand the increasing complexity of global urbanism, which can be partly attributed to China’s social segregation based on the household registration system (Hukou) (10). The country’s economic reforms have led to an unprecedented rural-to-urban migration, and this has contributed greatly to the rise of the urbanization level. Because the family planning policy has been implemented more rigorously in urban areas, and because many big metropolitan areas (such as Shanghai) have already experienced negative growth of their own native populations, recent rises in urbanization level and in the number of urban residents have mainly been due to changes in city scale and urban territorialization (11) and the settlement of migrants. Unprecedented rural-urban migration has reshaped the geographic distribution of the Chinese population. As in other eastern Asian countries, the demographic transition created a favorable impetus that contributed to the nation’s rise (12). Lower fertility increases women’s participation in the labor force and helps to improve levels of education, health, and nutrition. Lower fertility reduces the dependency ratio—that is, the ratio of the working-age population to the younger and older (nonworking) segments of the population—within families. Lower fertility also increases opportunities to acquire income beyond the basic necessities of life. For China as a whole, the labor force continues to increase as a result of the high fertility of two or three decades ago. The working-age population (aged 15 to 64), according to the 2010 census, accounted for 74.5% of the total population—a much higher share than that of many developed and developing countries. This results in a low overall dependency ratio (Table 2). Millions of young peasants migrate into the cities to match the strong growth of labor demand in the manufacturing and service industries, which also has been encouraged by various reforms of the social security and welfare systems. As a result, China has been able to have more investment and savings and a steadily rising gross domestic product (GDP). In other words, China has happily enjoyed its so-called “demographic bonus” during the past 30 years (13). But the window for harvesting this bonus may close soon (14). China has avoided a massive population explosion, but there have been huge social and economic costs. The abnormally masculine sex ratio at birth is one such example. This was first reported in the 1980s and has worsened since then. The latest census reveals that in 2010, for every 100 newborn girls there were 118 boys. The current male-to-female ratio of 118 is slightly lower than the figure reported previously, 119 in 2005, even though tough policies and measures have been introduced to address the issue in the past decade. There are marked regional differences in this regard. In general, the abnormalities are less severe in some western provinces and the autonomous regions, but more serious in the central and southern parts of China. Strong son preference and widely available pre-birth sex identification and sex-selective abortion are the main causes of this gender imbalance at birth (15).

Another major consequence of China’s demographic transition is rapid population aging. The country reached the threshold of an aging society (i.e., population aged 65 and above accounting for more than 7% of the total population) in 2000. The aging process has progressed very rapidly as the cohort of baby boomers has reached the retirement age. By 2010, the population aged 65 and above amounted to 118.8 million, versus 100.45 million in 2000. It is interesting to note that in eastern China and the major urban centers, the aging process has slowed because of the immigration of many young laborers from the countryside (Fig. 1A) (16). However, in turn, this leads to a more serious aging challenge in the rural areas (Fig. 1). Moreover, aging in China is occurring at a much earlier stage of socioeconomic development than seen in European countries and in Japan.

What lies ahead for China’s demographic transition?

China’s population will certainly grow in the future, even though the current TFR is well below the replacement level of 2.1. However, two key questions remain: (i) For how long will this growth continue? (ii) What will be the peak future size of the population? Given the current sociopolitical setting, the government’s population policy will be one of the decisive factors that determine the answer to these questions. There is a consensus that the mortality rate will continue to decrease, although perhaps on a slower path. Therefore, differences in population projections are mainly due to varied assumptions regarding the family planning policy and the fertility level.

Many population projections for mainland China have been made by scholars and organizations both in and out of China. It is impossible to cover all of them in this article; therefore, only a few are selected for discussion. Figure 2A refers to projections that assume a constant fertility rate, and Figure 2B shows projections that allow for changes in population policy and consequent change in fertility rate. All projections agree that China’s population will continue to grow for at least another decade. However, there are marked differences in terms of the peak population, which ranges from 1.35 to 1.507 billion because of disagreement about the present fertility level in China. Projections made by Goldman Sachs are exceptional, showing that China’s population will continue to grow even after 2050. By assuming that the current policy remains unchanged and assuming a TFR of 1.6 to 1.7, Zeng (17) and NPPFC (National Population and Family Planning Commission of China) (18) project that the population will reach a peak of around 1.41 billion in 2025 (Fig. 2A), which will be followed by a rapid decline after 2030. The latest version of projection made by the United Nations Population Division (19) is very much in line with this. Assuming a TFR of 1.47, a rate lower than the official one, Wang Feng projects a peak population of 1.35 billion in 2023 (20). Goldman Sachs (21) based their projections on detailed assumptions from the World Bank Population Unit (slightly adjusted toward the UNPD medium-variant standard) and claimed that the population will continue to grow during the next 40 years, and that in 2050 its size will reach 1.53 billion. The projections shown in Fig. 2B are based on varied assumptions with regard to population policy. Relaxing the current “one-child policy” to a “two children for one-only-child couples” (i.e., couples in which one party was an only child) policy (22) will lead to a peak population of about 1.45 billion in 2030 (18) or 1.49 billion in 2037 (17). If there is a shift to a universal “two children for all couples” policy, then China’s peak population size will be about 1.5 billion, reached in 2030. Under the “two children with late childbearing” scheme, the peak population will be about 1.48 billion in 2038. With entirely different assumptions, Goldman Sachs (21) assumed a total relaxation of the “one-child policy” from 2010 onward, with the result that the population will continue to grow to 1.67 billion in 2050.

Except for the projection made by Goldman Sachs, most recent projections—including others not mentioned in this review—envision a peak population for mainland China of around 1.45 billion to 1.5 billion, a figure that will be reached around 2025 to 2030. In fact, there is a near consensus among researchers that the country’s population growth will be slower, and stop earlier, than previously projected; for example, the earlier forecast made by NPPFC, assuming no policy change, projected a peak population of 1.6 billion by 2035. The age structure of the population is an important component of the projections. As shown in Fig. 2C, aging will undoubtedly characterize China’s demographic prospects for much of the 21st century. Population aging is foreseen under all scenarios and is roughly comparable. The proportion of the elderly aged 65+ will slowly exceed 10% from now to 2015 and then rise rapidly, reaching 20% and 25%, respectively, in the periods 2015–2035 and 2040–2050 (17, 18, 23). The absolute size
of the elderly population is expected to reach 200 million by 2025 and 300 million by 2040. In addition, note that the proportion of the population aged 65+ under the “current policy unchanged” scenario will be higher than in other scenarios by an appreciable degree. This is because lower fertility will inevitably mean more rapid aging (18).

Although the increase of the elderly population will surpass the rest of the age groups, the working-age population (aged 15 to 64) in China will remain enormous, both in terms of absolute size and as a share of the total population. The influence of potential adjustments in population policy on the size of the working-age population will only emerge after the period 2025–2030. All projections show that China’s working-age population will continue to grow in the next decade, that it will reach a peak of around 980 to 1000 million around 2016–2020, and that this will then be maintained for a while. The shrinking of the working-age population is more or less inevitable around the time that the population stops growing. The size of the working-age population will largely be determined by changes in population policy and the prevailing fertility level. The working-age population would gradually decline to 800 million under the “current policy unchanged” scenario and would be a little less than 900 million under the “two children for one-only-child couples” scenario. Varied policy adjustment and TFR options can result in the size of the working-age population in China ranging between 780 million and 1000 million in 2050.

Moreover, the huge migration involved in the process of urbanization has always been regarded as one of the motive forces of China’s economic growth and development. The scale and pace of urbanization promise to continue at an unprecedented rate. If current trends hold, the urban population will expand from about 665 million in 2010 to 926 million in 2025 and will hit the 1 billion mark by 2030 (24). This means that China’s cities will add 335 million people in the next 20 years—more than the entire population of the United States today. Most of these 335 million new urban residents (240 to 260 million) will be rural-urban migrants. This growth will undoubtedly imply mounting pressures for many cities. After all, there will be 219 cities with more than 1 million inhabitants by 2025, compared with just 35 in Europe today. Moreover, 24 of these cities will have more than 5 million people (24).

**Fig. 1.** (A) Provincial distribution patterns of the population aged 65 and over (left, 1982; right, 2010). (B) Provincial distribution patterns of the population aged 0 to 14 (left, 1982; right, 2010).
Uncertainty also comes from population migration. Whether Chinese cities can absorb ever larger numbers of newcomers under environmental and development constraints is unknown. Also, little is known about how urbanization will change millions of Chinese farmers' demographic behavior and further affect future demographic trends.

**Challenges and opportunities**

China is completing its demographic transition within a compressed time period relative to most other countries in the world. Although the country has benefited, particularly in terms of economic growth, from rapid and constant mortality and fertility decline and rapid urbanization, it also faces great challenges to adapt to these changes. If not properly managed, such adaptations could incur a variety of risks.

It is clear that demographic factors are crucial to economic growth in China. One-fourth (26%) of China's economic growth from 1965 to 2005 can be attributed to the growth of the working-age population (25). China's working-age population is estimated to peak at 1 billion by 2015 and will start to decline thereafter (19). As a result, the labor market demand/supply relationship is changing. On the other hand, even as one of the fastest-growing economies, China is struggling to keep up with millions of new entrants into the urban labor market, which needs to create about 20 million jobs annually to absorb both local labor market entrants and incoming rural migrants.

The slower growth and eventual decline of the labor force could constrain future economic growth and could have a profound impact on development (26). Excess cheap labor supply, which is one of the major factors driving China's economic miracle, will no longer be available; this will push wages upward and possibly reduce the global competitiveness of China's manufacturing exports. On the other hand, higher wages may increase internal consumption and standard of living. On the whole, this demographic change may transform China from an "abnormal economy" into a "normal dynamic emerging economy" (27). Some have argued that it is approaching the "Lewis turning point" and that any demographic dividend is to be exhausted (33).

These changes in labor supply will inevitably lead to a geographic restructuring of the economy. Labor-intensive, export-oriented industrial clusters in the big city centers and the coastal regions may have to move into inland provinces where cheap labor is still available, or may be transferred to other developing countries.

With the working-age proportion beginning to decline in the country, it will be a good chance for China to raise the legal retirement age, currently set at 60 years for men and 55 for women. This is an arrangement that was introduced in the early 1950s, when life expectancy at birth was only about 40 years. Furthermore, regulations and policy measures should be adapted to increase old-age labor force participation and to remove direct or indirect barriers to workers continuing in employment beyond the normal retirement age.

Another response to the potential labor shortage in China is to improve labor productivity by investing more in human capital and skills, by moving up the value chain and creating higher-productivity jobs, by more efficient allocation of labor between sectors, and by improving the efficiency of the labor market. Remarkable success has been achieved in raising the educational level of the Chinese people over the past several decades. The latest popu-

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**Fig. 2.** (A) Chinese population with current policy unchanged, 2010–2050. (B) Chinese population under policy change scenarios, 2010–2050. (C) Chinese population age structure, 2010–2050.
The Chinese government has committed to increasing its investment in education, but public spending on education was only 3.59% of the GDP in 2009—a figure lower than in many developing countries. China must make the transition from a country with a large labor force to one with abundant human capital (29). To reach this end, more innovation and reform in China’s overall education system are absolutely required.

The elderly population will increase markedly over the next half century, both in terms of absolute numbers and as a proportion of the total population. At present and for the near future, the very large younger segment of the old-age population (i.e., people in their 60s) is the result of the baby boom in the 1950s and early 1960s. However, the proportion of the oldest old (i.e., 75 years and over) will increase substantially within about 20 years. This will put huge pressure on pension and health care systems.

China introduced a Western-style pension system in the late 1990s, and the system today is divided along rural-urban lines and regionally fragmented with decentralized financial and administrative management (30). The existing social protection arrangements, including pension, in China is in itself inequitable and therefore tends to broaden the urban-rural and regional gap rather than narrowing it (31). By the end of 2010, the Urban Basic Pension System covered 257 million urban residents, or about 40% of the urban population. In addition, 100 million rural people—15% of all population living in the countryside—have joined the new rural social pension system (32).

Moreover, the sustainability of these systems is a major issue. Huge deficits in the country’s pension system are expected if no further reform is conducted. Some argue that under the current system, assuming a replacement rate (pension as a percentage of final salary) of 52%, an annual deficit in the urban basic pension system will emerge as early as in 2015, and the total deficit would be equivalent to 95% of the total annual GDP in 2050 (33). Relaxation of current family planning regulations and a higher fertility rate may ease the future burden of any pension deficit to some extent, but it cannot reverse the general aging trend. More reforms of the integrated multi-pillar pension arrangements must be carried out to expand the financial and service resources for old-age support and make the system more equitable (34).

The government launched its ambitious universal medical insurance program only a few years ago. By 2010, the urban basic medical insurance scheme covered 432 million people, or two-thirds of total urban residents. In the countryside, 95% of farmers joined the new rural cooperative health-care system. The quality of and accessibility to the public health service varies among regions and among different social strata; this has become an issue of social justice and equity. Demographic changes, and population aging in particular, will certainly be one of the main causes of increasing expenditures for medical service. Although it is crucial to provide better medical service to the elderly population, it is equally important to promote a healthy lifestyle among younger age groups.

One of the results of China's demographic change is the weakening of family capacities and functions. The traditional family support system is eroding with migration and fewer children per family, and this will present a great challenge to the continuation of the country's cultural traditions. There is a whole generation of families, or about one-quarter of all families, that have only one child. The size of the single-child group amounts to more than 100 million at present. The single-child generation has some special characteristics (such as self-centeredness) and behaves differently from other generations, although the difference may not be as big as is commonly stereotyped (35). This unique demographic phenomenon will certainly influence the country’s socioeconomic development and its political future as well. However, systematic research on the potential societal impacts of adults who grew up in single-child families has been extremely limited.

The severe imbalance in sex ratio at birth is expected to be gradually reversed in the near future, and the consequence of this phenomenon—which lasted for three decades—will soon begin to emerge. By 2025, China will have a deficit of young females at typical marriage ages ranging from 20 million to 30 million (36). A severe “marriage squeeze” (the extent to which changes in marital ages by sex reflect the relative supply of potential husbands and wives) is expected and has become the most widely discussed implication of sex-selective abortion, not only in scholarly literature but in the popular media as well. The marriage squeeze may lead to serious instability in the institutions of marriage and family and consequently poses a great threat to the stability of the country’s social order. The poorest poor in China’s countryside will be the social group suffering most. Changes in marriage pattern, including importation of brides from abroad, are expected, although the factors that may alter the pool of potential spouses are much more complicated. Marriage squeeze will inevitably affect the country’s future development in all aspects, even its huge foreign exchange reserves (37).

As the world is becoming more urbanized around both megacity regions and smaller cities, China offers valuable lessons on the continued power and limitations of top-down state planning relative to the growing influence of global capital and local markets in shaping megacity regions on the booming coast and smaller centers in the less-developed interior. The Chinese government has just published a national plan that has defined the functions of regions at local levels with differentiated policies to sustain the country’s development. Local governments must optimize, accelerate, restrict, or prohibit industrial development and urbanization as well, in different regions according to the national plan of the development priority zones (38). Although state-guided development of major city regions will continue to drive urbanization and economic growth in China, increasing differentiation in catch-up development—in conjunction with varied historical conditions and local endowments—may become more important in determining the future trajectory and socioeconomic consequences of urbanization in China (39).

With its huge population, China must find ways to sustain and conserve natural resources. An ever-increasing population will inevitably exert greater impacts on China’s already troublesome food supply, water shortage, and environmental pollution problems.

Per capita water resources in China are only about 2200 m³, about one-fourth of the world’s average. With population growth and industrial development, water shortages have already affected major cities and have become one of the bottlenecks for sustainable development. China may be caught between growing demand for fresh water on the one hand and limited and increasingly polluted water supplies on the other.

China lost around 12.4 million ha of arable land between 1980 and 2008. This reduction in arable land can be attributed to three main factors: industrialization, construction of residential buildings, and land degradation. With a constantly decreasing arable land area and continued increase of the population, China is getting closer to the threshold of arable land scarcity, whose rough benchmark was defined by geographer Vaclav Smil at 0.07 ha per person (40). China may have the ability to ensure food supply by intensifying the use of land and increasing reliance on modern material input and agricultural technology (41). China’s demand will certainly affect international food markets and the global food balance.

China is already among the largest emitters of carbon dioxide in the world. Population growth is viewed as one of the decisive factors that will drive future climate change. New research suggests that, in addition to population size, changes in population structure, urbanization, and household size also contribute to climate change. Urbanization leads to a substantial increase in carbon emissions, whereas the aging process leads to a decrease.
The net effect of demographic change is to increase projected emissions for China by 45% over time (42). However, the demographic impact on climate change should not be overstated, as it accounted for only one-third of the country’s emission increase; industrialization, urbanization, and consumption are more important factors determining future carbon emissions in China (43).

Demographic changes in China will have important global impacts. Given all of the factors discussed above, a future population decline may be desirable for China. But rapid or even sudden population decline would be disastrous, and it would be very difficult to stop. Maintaining the present low fertility would be worrisome. Overall, it would be rational for China to modify its current population policy and to relax the rigid control on childbearing sooner rather than later, and to allow the TFR to grow and be maintained at around 1.8 in the near future. Then the country’s population would decline and its aging process would be slower in the future, which would provide more time and a better social environment for China to cope with future population-related socioeconomic changes. China’s population issues should be dealt with in an integrated and balanced way.

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22. According to current “one-child policy,” if both spouses were single children themselves, they can have two children. “Two children for one-only-child couples” refers to policies that allow couples in which one of the spouses was a single child to have two children. “Two children for all couples” refers to policies that allow all couples to have two children.
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Aging challenges in China: Rapid development, significant burden, and national priority

Shuang Rong and Yuexin Yang*

People born in the 1950s, when China’s first population boom took place, are now reaching 60 years of age. This suggests that China will soon face an aging society, creating a growing concern of a serious health care crisis. According to a report entitled “The Blue Book of Aging - China Report of the Development on Aging Cause (2013)” released by the Chinese Academy of Social Sciences, the portion of the population aged 60 years or over in China was approximately 194 million in 2012 and is expected to reach 202 million in 2013 (1). In the next 30 years, from 2010 to 2040, China will see an increase of 15.7 percentage points in the proportion of those aged 60 years or over (from 12.4% to 28.1%), the fastest rate of growth in the world (1,2).

Further exacerbating the challenge of an aging society is the shifting demographics of the elderly population. According to the 2010 census, of those over 60, 56% are aged 60 to 69, 32% are between 70 and 79, and almost 12% are over 80. Compared with census data from 2000, the proportion of over-60’s in the 60–69 age group has decreased by 2.66%, while the over-80 group increased 2.59% (in real numbers, up from 12 million in 2000 to 20 million in 2010) (3,4). Twenty-three million persons aged 80 years or over were living in China in 2013, making it the country with the largest population of persons in that age group. This fact is expected to hold true through 2050, when the estimated number will be 90 million (2).

Population health by the numbers

The most recent estimate of the average life expectancy in China is 74.83 years (males 72.38 years and females 77.37 years) (3). To analyze the healthfulness of this aging population, Du et al. used self-reported health data from China’s 6th National Population Census in 2010 to conduct a comprehensive analysis of the health status of those over 60 years old. Overall, the health status of this age group was found to be good, with 43.9% self-identifying as having good health and 39.3% saying their health status was moderate (5). By contrast approximately 30 million, or 16.85% of the total, indicated that they had an unhealthy status. Disabilities were reported by approximately 3% of respondents, equating to an estimated 5.24 million aged people who require long-term care. Reported health status declines with advancing age: those reporting good health status declined from 60.8% in 60–64 year olds to 48.4% in 65–69 year olds, 35.2% in 70–74 year olds, and 28.0% in 75–79 year olds. The percentage of those with a disability increased dramatically from 12.7% in the 85–89 group to 26.1% in the 95–99 group.

The data also indicated that the urban elderly are healthier than those living in a rural environment, with 49.9% of urban residents self-reporting good health compared with 40.4% of rural residents. Additionally, the percentage of aged people with a disability in rural areas (3.3%) is higher than that in urban contexts (2.5%) (6). Demand for health services is high in both rural and urban settings (7,8), and the two-week prevalence of chronic disease and hospitalization rates have increased dramatically from 2003 to 2008 (Table 1). The percentage of patients in urban contexts who had physician contact within the two-week duration of the study was higher than that in rural areas in 1993, 1998, and 2003, but these differences disappeared by 2008 (9).

An epidemiological shift

As the aged population grows and life expectancy increases, health in old age has become an important goal, including avoidance or effective management of chronic age-related diseases, prevention or retardation of the progressive decline in physical and cognitive function, and maintenance of psychological health.

China has seen a rapid epidemiological transition in the past few decades as the predominant cause of mortality has shifted from infectious diseases and perinatal conditions to chronic diseases and injuries (10). China’s aging population structure is resulting in higher ratios of chronic diseases commonly seen in older age groups. According to the 2013 China Health Statistical Yearbook, the prevalence of chronic disease in people aged over 65 in 2008 was 64.54% (85.18% in urban areas and 52.39% in rural). Cancer was the leading cause of death in the 60–80 age group, while cerebrovascular and heart disease had greater prevalence among those over the age of 80 (9). Using data from the Global Burden of Disease Study 2010, Yang et al. found that in China, stroke had the largest health and well-being impact on individuals. Stroke and ischemic heart disease accounted for 15.2% of all Disability Adjusted Life Years (DALYs; a measure of years of healthy life lost) in 2010, with DALY rates from stroke being almost twice as high as ischemic heart disease (11).

Cognitive dysfunction and mental disorders have also been critical diseases which affect the health and quality of life of the elderly. The prevalence of dementia in China is between 3% and 5% of the total population over 60 years of age (13), while the prevalence of mild cognitive impairment (MCI)—a marker of pre-dementia syndrome—is 12.7% (CI: 9.7%–16.5%) (14), and the prevalence of depressive symptoms among the population aged 60 years is 22.7% (CI: 19.4%–26.4%) (15).

Dietary risk factors, high blood pressure, and tobacco exposure are the risk factors that constituted the largest number of attributable DALYs in China (11). Public health programs to reduce sodium intake, fat consumption, and change other dietary risks are clearly important strategies for improving health of the elderly in China.

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<th>Year</th>
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Future plans and countermeasures
The broad impacts of dealing with an aging population means that China is facing a substantial challenge to its social management and policy systems, including pension, medical care, home-based services, and public resources allocation. Measures need to be introduced to financially support the rapid expansion in the size of the elderly population, particularly since many of those over 60 have not generated enough fiscal resources to support themselves after retirement. The Chinese government has been developing some strong policy measures to implement a number of key actions including social insurance and policies that help the elderly remain in their homes and play an active part in their community. In 2012, the 18th National Congress of the Communist Party of China developed a strategic plan to actively deal with the challenge of population aging. As a result, an updated version of the Law on the Protection of the Rights and Interests of the Elderly of the People’s Republic of China was released. The law has now been passed and enacted, and a series of policies have been announced that safeguard the legal rights and interests of the elderly.

As the Chinese population ages, the issue of health problems in the elderly becomes paramount. To address this, healthy aging strategies have been included in national economic and social development long-term planning in China. The most urgent problem facing the aging population is the potential for soaring health care costs, especially those related to chronic diseases. Balanced nutrition can help to protect the elderly from certain chronic diseases and also improve quality of life, which would be a powerful driver in improving both the health and the economic status of society as a whole (10). Studies have demonstrated that, from providing just a basic level of adequate nutrition, to refining normal diets by adding healthier foods or removing unhealthy foods, to the introduction of functional foods designed to provide health benefits beyond normal levels, improved nutrition is not only the consequence of economic development, but also a motivational factor that plays an important role in driving economic development (16). With increasing pressure on health care budgets across the world, the economic potential of nutrition-related health effects attracted many researchers’ and policymakers’ attention. Finding the optimal way to accelerate the development of nutritional and health policies based on long-term considerations that meet the needs of the elderly has become a major issue facing China today.

In conclusion, to achieve the goal of a healthy aging population in China, the following considerations should be addressed. First, basic medical security needs to include equitable access to multilevel medical health care for all patients, whether they live in urban or rural situations. Second, medical health care capabilities at the grass roots level should be upgraded, especially the prevention and management of chronic diseases including drug and non-drug interventions. Third, regulations, policy measures, and law reforms need to be drafted to ensure that there is adequate pension support for all Chinese citizens as they age. And fourth, prevention remains the most viable avenue for lessening the disease burden and generating substantial health benefits, including nutrition education and good dietary practices such as reducing the amount of oil and salt used in traditional cooking. It is worth reiterating the importance of creating a culture that supports good dietary nutrition and treatment to ensure that all elderly people can enjoy adequate health care and a good quality of life in their home and hospital (10).

References
Why a macroeconomic perspective is critical to the prevention of noncommunicable disease

Richard Smith

Effective prevention of noncommunicable diseases will require changes in how we live, and thereby affect important economic changes across populations, sectors, and countries. What we do not know is which populations, sectors, or countries will be positively or negatively affected by such changes, nor by how much. Without this information we cannot know which policies will produce effects that are beneficial both for economies and for health.

Bill Shankly (manager of Liverpool Football Club from 1959 to 1974) said football (soccer) is “not just a matter of life and death, it’s more important than that.” For economists, so are noncommunicable diseases (NCDs) (1). Not only are the effects of NCDs felt throughout the economy (Table 1), but since the agents contributing to NCDs are influenced by our lifestyles, effective preventive policies are likely to include mechanisms that themselves have appreciable economic impacts, such as taxing soft-drinks, increasing the use of public transport, or promoting lower-polluting energy sources (2, 3). Although the impacts of such policies may improve health, there will be substantive economic impacts as they ripple out through the economy, generating differential effects across various sectors, such as housing, transport, and agriculture. These economic effects may generate yet further health effects, which themselves then feed into the economy, generating yet more cycles of effects. This interaction and reciprocity between NCDs and the economy highlights the critical need for a macroeconomic perspective in the design, implementation, and evaluation of preventive policies to tackle NCDs.

Macroeconomics, as compared with microeconomics (which is focused upon “partial equilibrium” within a single sector, such as for housing or meat), is concerned with general equilibrium across all sectors, and thus how changes in one sector (e.g., increase in price) affect other sectors, with all these changes together comprising the overall “economic impact” of a single change (4, 5). For instance, the impact of pandemic influenza on the healthcare sector is minimal compared with its effect on gross domestic product (GDP) through impacts on other sectors (e.g., hotels, leisure, travel), which are a consequence of changes in individual behavior in response to pandemic threat and the mitigation policies themselves (6, 7).

Why is this important for NCD prevention?

NCDs, such as diabetes, cancer, and heart disease, differ from infectious diseases, such as pandemic influenza, as they are not transmitted from person to person (although there is evidence emerging in the social sciences of “social contagion,” where social networks appear to influence the probability of obesity, for instance (8)). However, they also differ in that they are intrinsically lifestyle diseases, and hence the cause and impact are linked in a multiplicity of ways to everyday economic activity (Fig. 1).

NCD-related health (Fig. 1, box 1) is determined directly by risk factors (Fig. 1, box 2), which include genetic predisposition to disease, such as diabetes and heart disease, but also by a range of other social determinants of health, which refer to the general conditions in which people live and work, including levels and types of employment, environmental conditions, and education (9). These social determinants contribute to the risk of different diseases, such as pollution-related diseases and cancer. They are also intimately linked with the household and individual (Fig. 1, box 3), which represent how people behave and, crucially, invest (or disinvest) in their health by what they consume and in the activities they undertake (8). For example, cancer and heart disease risk will be affected by decisions concerning smoking, alcohol consumption, and exercise. But risk will also influence household and individual behavior. For instance, an individual’s knowing that they have a higher genetic risk of heart disease may modify individual consumption of fast-food. The healthcare sector (Fig. 1, box 4) comprises goods and services consumed by households principally to improve health status. Although these affect NCD-related health directly, they also impact on the household economy, which ultimately pays for them through taxation, insurance, or out-of-pocket. The level of ill-health caused by NCDs will also feed back and impact on the household, thus further affecting the risk of other health problems through reducing household income, and feed into healthcare provision through shaping the demand for services, and hence profile of provi- dence (e.g., more insulin prescriptions).

Activity in all non-healthcare sectors in the economy (Fig. 1, box 5), such as agriculture, manufacturing, and education, impacts on the previous three components and, thus, NCDs. It is well established, for instance, that “wealthier is healthier” (10, 11), but that wealth also brings an increase in NCD risk, such as through changes in dietary habits, with the suggestion that in some cases this means that economic recessions can have positive health benefits (12). As countries grow wealthier, their populations experience increased desirability and availability of processed foods, perhaps mostly starkly indicated by the experience of some Pacific island populations where traditional diets have been displaced with high-fat imported foodstuffs and a concomitant increase in obesity rates and NCDs. Similarly, the transformation of food retail as countries become more integrated in the global trading system has facilitated a pronounced shift to the consumption of processed food, and multinational fast-food outlets have made substantial investments in growing economies (13). It is also accepted that health positively affects the general economy through a fitter, more educated, and more productive workforce (14). Insecurity, as labor moves from one sector or location to another, generates ill-health directly through the stress caused by economic and social dislocation, and indirectly by increasing poverty (15). Economic well-being, tax rates, and other aspects also affect healthcare spending.

Finally, influences beyond our political borders act on these components (Fig. 1, box 6). For instance, climate change is a global issue with local consequences for NCD risk factors. Problems with subprime lending in the United States, or the Euro crisis, will affect household employment, income, and inflation in the United Kingdom, too. The migration of health professionals affects the ability to provide services required to treat NCDs.

Prices are pivotal

For economics, prices are pivotal. They enable exchange of goods and services and, crucially, determine the point of equilibrium, where demand and supply are balanced. Any change within the economy will affect price directly or indirectly, which will then disrupt this balance, and each sector will then have to adjust to a new equilibrium through changes in other prices. It is a simple, largely automatic, system that has profound implications for NCD prevention—illustrated by the current enthusiasm for a “fat tax” as a mechanism for reducing consumption of foods high in saturated fat through increasing their price. Such a tax has been implemented in Denmark and Hungary and is now being considered by many others (16, 17).

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The argument is simple. The current price of foods high in saturated fat does not adequately reflect the negative health effects, leading to overconsumption (compared to a hypothecated equilibrium where such health effects were captured in the price). Government can apply a tax to address this “market failure,” which increases price. We know that, in general, increasing price leads to a reduction in demand, which reduces consumption, and thus should reduce rates of NCD. Microeconomic, partial-equilibrium analysis will tell us how sensitive this demand is to a change in price (which we know is actually not very sensitive in the case of most foods) and thus by how much price needs to increase (usually, therefore, a lot) (16). The problem, from a macroeconomic perspective, is that it does not tell us anything at all about how other sectors will adjust and thus we cannot know what the overall net impact on the wider economy, or even health, will actually be.

Consider an example where such a tax increases the price of beef. How might consumers react? Any change in price will cause a recalibration of expenditure across the range of goods and services that individuals consume, not just beef. At the extremes, consumers may either reduce spending on beef, to keep spending on everything else the same, or spend less on something else to keep beef consumption the same. What are the implications of these two scenarios?

If consumers reduce their demand for beef, then beef farmers will experience reduced income. Remember that the price is higher as a result of a tax, and hence this extra revenue per unit of beef goes not to the farmer, but to the government—generating further questions about what this tax revenue would be spent on, such as subsidizing fruit and vegetables versus reducing income tax, and the implications of that, which we don’t have time to consider here. As beef is less attractive to produce, farmers will transfer production to other products. Which other products is then the critical question. If it is biofuels, for example, this may have positive effects on the environment and thus further decrease risk factors for NCDs and multiply the health effect. Alternatively, if farmers switch to producing lamb, the increased supply will mean that the price of lamb will fall, and it may largely replace beef in the national diet, negating health benefits from reduced beef consumption.

Farmers could instead focus on increasing exports of beef, thus increasing consumption, and rates of NCDs, in other countries and effectively “exporting” the health problem. What if the beef consumed in one country is imported from another? In this case, it is possible that a tax may not be able to be levied, as it may violate World Trade Organization requirements if the country is a member state. But if a “fat tax” could be levied, then there are economic advantages as less income would be transferred overseas as beef imports declined (which will affect balance of payments and currency valuation with further spillover effects). However, again there could be negative health and economic implications for the countries from which the beef was imported. For example, although changing to a healthy diet may be beneficial for the United Kingdom, if this is achieved through reduced imports of beef, then Brazil (as the world’s largest exporter of beef) may see a substantial negative impact on its economy, and consequently its population’s health (18).

But what if consumers keep consuming beef, and instead spend less on something else? If less is spent on fruit and vegetables, for example, then this could make health worse. Alternatively, consumers may spend less on car travel, which could have further positive health benefits from reduced emissions, or spend less on leisure activities, possibly having negative health implications from reduced exercise, and certainly having economic implications for those sectors. Or they may spend less on flat-screen televisions or computer games, perhaps generating positive health effects if this leads to increased active leisure pursuits. As above, this spending reduction may affect imported goods, generating effects on the balance of payments of other countries and exchange rates. The ripples continue.

Thus, we know that such a food tax would impact directly on consumption patterns, but after that we know little about what will happen. A food tax will affect the risk of NCDs in an unpredictable manner as it begins to indirectly influence other sectors in the national economy and interface with the rest of the world. If the net effect is to increase health, then this should feed positively into the economy itself, by reducing healthcare costs and by improving workforce productivity. However, we do not know that this will be the effect, because we do not consider the broader macroeconomic picture.

What is the solution?

We know that a more comprehensive and integrated economic approach is required for developing optimal strategies for preventing and coping with NCDs; the health sector alone cannot achieve the required reduction in NCDs. We also know that there will be differential effects from these strategies across populations, sectors, and countries. What we do not know is which populations, sectors, or countries will be positively or negatively affected, or by how much.

As indicated above, to generate the most effective and acceptable policies to improve NCD prevention there is need to engage with macroeconomic factors to generate optimal prices, subsidies, safety nets, trade agreements, and so forth if a country decides it is advantageous to nudge its population toward healthier behavior. This presents several challenges, such as the specification of causal pathways and mechanisms to reconcile and balance non-health (e.g., employment) versus health outcomes. Thus, to make the unknowns known will require a substantial paradigm shift in academic, professional, and policy circles (19). Critically, studies concerning the whole-economy effects at a global level are required. Current evidence tends to focus either upon the broad,
general, effect of changes in disease upon the economy, or of changes in the economy upon disease (22), or focus upon a specific sector (e.g., studies concerning “fat taxes” tend to consider the impact of a price increase only on the food of interest) (16). Very few studies consider the cross-sectoral or cross-country causes or impacts of NCDs, and measures that may be used to prevent NCDs, or integrate the economic and health effects (18). Yet without this information, we cannot know which policies will produce net beneficial effects, for the economy or health, or what countervailing policies may be required to minimize negative spillovers.

Because NCDs affect the economy so profoundly and pervasively, we also need to quantify these effects, as it is often the economic case that swings the agenda and mobilizes resources. The history of communicable disease, in this respect, provides valuable lessons. The economic impact of HIV/AIDS, tuberculosis, and malaria in particular was important in mobilizing initiatives such as the President’s Emergency Plan for AIDS Relief and The Global Fund to Fight AIDS, Tuberculosis and Malaria. This was due in part to the WHO Commission on Macroeconomics and Health in 2000, which established firmly that investments to reduce such diseases would be a primary driver of macroeconomic development (14). Having HIV/AIDS as the first health-focused UN high-level meeting in 2001 was also prompted by the devastating effect the virus was having on African economies (14). The second health-focused UN high-level meeting on the NCD challenge, in 2011, also stressed the economic impact of chronic disease (1). With the resolution of the 65th World Health Assembly in 2012 to reduce premature deaths from NCDs by 25% by 2025, the imperative now is to formulate strategies to achieve this target, which requires us to recognize that NCD prevention is “not just a matter of life and death, it’s more important than that.”

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Section 2: Malnutrition at different life stages and the importance of nutritional intervention

Malnutrition impacts all life stages, from conception to the final golden years of life, in both health care and community settings. Often underrecognized and undertreated, malnutrition can have a serious impact on public health. Clinical and health economics research is advancing the body of evidence further demonstrating the vital role of screening, diagnosis, and treatment interventions for malnutrition. Intervening with proper nutrition is critical to improve health and associated nutrition-related health outcomes. The articles in this section describe some of the unique challenges encountered at each life stage.
Despite gains, malnutrition among China’s rural poor sparks concern

Richard Stone

BEIJING—From SARS to bird flu to a lethal new bunyavirus, China is a crucible for deadly pathogens. But to Wang Yu, director of the Chinese Center for Disease Control and Prevention here, no microbial scourge now in circulation poses as stark a threat to society as malnutrition.

One of the most visible manifestations of malnutrition is stunting, defined as being two or more standard deviations below World Health Organization (WHO) standards for median height by age. Stunting rates in China have declined dramatically, from 33.1% in 1990 to 9.9% in 2010. However, recent trends trouble health officials here. After the global economic crisis in 2008, stunting rates rose in poor areas of rural China. And despite the tremendous gains in the past 2 decades, nearly 6.5 million children under age 5 in China are stunted.

Stunting in early childhood has grave and lasting consequences. “The data linking stunting to poor cognition, low adult wages, and lost productivity are very solid,” says Mercedes de Onis, coordinator of WHO’s Growth Assessment and Surveillance Unit in Geneva, Switzerland. China draws much of its labor force from the countryside. “When the new generation grows up, it will be too small and too weak to support society,” Wang argues. “China’s future depends on the country’s ability to provide adequate nutrition.”

In an initiative now underway, Chinese CDC is seeking to improve nutrition for infants and young children, especially in the countryside. “We will systematically collect data to make people realize the severity of the challenge,” Wang says. Toward that end, Chinese CDC this year plans to double the 100-strong scientific staff of its Institute of Nutrition and Health. The agency also intends to expand a pilot project carried out in Gansu Province several years ago, in which infants whose diets were supplemented with whole-fat soybean flour fortified with micro nutrients scored higher on intelligence tests and had better motor skills than infants given rice flour or no supplements. “This is the first time the child nutrition issue is on the government’s agenda,” says Chinese CDC nutritionist Chen Chunming, former president of the Chinese Academy of Preventive Medicine.

Experts warn that food security could erode, threatening recent gains in China and the developing world. Across Asia, WHO estimates, the number of stunted children under age 5 fell from 190 million in 1990 to 100 million in 2010; prevalence receded from 49% to 28%. The prevalence of underweight young children also declined, from 33.8% in 1990 to 19.5% in 2010. China has logged similar progress since establishing a childhood nutrition surveillance system in the early 1990s. In synch with China’s torrid economic development, stunting prevalence in young children in poor rural areas fell from 36% in 2000 to 18.9% in 2008, Chen and CDC colleagues reported in the July-August 2011 issue of Biomedical and Environmental Sciences. Until 2008, Chen says, “we saw a really dramatic change.”

She and others expected China to protect those gains after the 2008 economic crisis, as massive stimulus spending kept the country’s economy growing at a healthy clip and the government implemented measures to keep farms productive. On the whole, China fared well: Chinese CDC estimates that nationwide, the number of stunted children under 5 years old receded from 8 million in 2005 to 6.5 million in 2010. Parsing the data further, however, Chen’s team found that in poor rural areas, stunting prevalence under age 5 rose from 18.9% in 2008 to 20.3% in 2010. In infants under 12 months in those areas, stunting nearly doubled from 2008 to 2009.

Malnutrition’s pernicious effects are apparent to anyone who ventures into China’s impoverished countryside, where “many people have very small bodies,” Wang says. “Children who are 12 or 13 years old look like 8- or 9-year-olds,” he says. “Body development is lagging, and most children never catch up.”

Wang is not alone in hoping to steer the nation onto a more robust trajectory. Last autumn, the education ministry announced a $2.5 billion, 5-year program to improve school meals for 26 million kindergarten through 12th grade students in 680 poor counties in China. That program will help, Wang says, but by the time children are in school, he cautions, “it’s too late” to head off stunting-related deficits.

To eke out further gains, China may look to Brazil, which slashed stunting rates in its impoverished northeast from 34% in 1986 to 6% in 2006. “The Brazilian experience shows that the scourge of chronic malnutrition can be rapidly reduced if income among the poor rises and simultaneously there is increased access to schools, clean water, sanitation and basic health care,” de Onis and colleagues reported in the January issue of Public Health Nutrition.

China is not as resource-rich as Brazil, Wang says: “We don’t have enough farmland and in particular enough water.” China may have to ratchet up imports of staples while better utilizing its own scarce resources. Bearing that in mind, Wang is reaching out to other ministries. “We have to integrate our nation’s expertise in nutrition, agriculture and economics,” he says.

For the sake of the next generation, Chen says, China cannot delay: “It’s crucial to act immediately.”
Maternal malnutrition and the long-term health of populations: A new paradigm in health care

Chittaranjan S. Yajnik

Until recently, a successful pregnancy was equated with the delivery of a live baby, together with an additional minor concern about the baby’s weight. There was little appreciation that the health of the baby in utero is intricately linked to its overall childhood and adult health. David Barker and colleagues changed this paradigm when they demonstrated that maternal nutrition influences the future risk of noncommunicable diseases (NCDs) in the baby (1). There is increasing understanding that these influences may span more than a single generation, and that non Mendelian, modifiable epigenetic mechanisms contribute to the heritability. Against this background, we are investigating the influence of maternal nutrition on fetal growth and its risk for future NCDs like diabetes, hypertension, and cardiovascular disease (CVD).

Around the globe, a major concern is maternal undernutrition and its effects on pregnancy outcomes and neonatal health. In the last three decades, an estimated 15% of reproductive age women (20 to 49 years) have been reported to be chronically undernourished (BMI <18.5 kg/m²), with the highest proportion in Asian countries (~18%) (2). Survey data from India found that 36% of women aged 15 to 49 years had a BMI <18.5 kg/m² (3). The aggregate effect of maternal undernutrition (through fetal growth restriction, stunting, wasting, specific nutritional deficiencies, and suboptimal breastfeeding) contributed to an estimated 3.1 million child deaths in 2011, accounting for 45% of all child deaths (2).

The nutritional double burden

In many parts of the world, concerns about maternal undernutrition have now been replaced with concerns about overnutrition. In the developed world (United States and Europe), as many as three-quarters of mothers are reported to be overweight or obese (BMI >25 kg/m²) (2). Excess maternal weight can adversely affect outcomes during pregnancy (increased incidence of diabetes and hypertensive disorders), delivery (hemorrhage, caesarean delivery, macrosomia, birth trauma, and infections), and postpartum (higher weight retention and failure of lactation). In the low and middle income countries (LMICs) undergoing nutritional transition, the proportion of overweight and obese pregnant mothers is increasing (2), due to urbanization, increasing age at the time of conception, and other lifestyle factors (4). Both undernutrition and overnutrition in the mother are transmitted to the child, setting up a cycle of intergenerational malnutrition, which disproportionately affects female children.

A rapidly changing epidemiology due to demographic and nutritional transitions produces a double burden of undernourishment in early life with relative overnutrition and NCD in later life. This creates additional challenges for health care providers and policymakers trying to manage the health of the population. It is notable that those parts of the world contributing the largest proportion to the burden of undernutrition in early life (LMICs), also suffer from NCD epidemics such as type 2 diabetes, hypertension, and CVD (Figure 1) (5).

Nutrition and disease

The idea that undernutrition in utero might influence future risk of NCDs was first documented in studies of Dutch men and women who were fetuses during the so-called hunger winter of World War 2 (6). Rationing during this time reduced food intake to about 600 calories per day per person. Follow up studies showed that male offspring who experienced hunger during the first two trimesters of pregnancy were at increased risk of obesity later in life, compared to those born outside of the hunger winter. On the other hand those undernourished in the third trimester were less likely to be obese. It was postulated that the increased obesity in the former group was due to resetting of the hypothalamic appetite centers, while in the latter group, reduced number of adipose cells decreased obesity. Subsequent studies have provided further evidence of the increased risk of diabetes, hypertension, and other NCDs in those who faced the hunger winter in utero (7). A recent study in China demonstrated an increased risk of diabetes in those who faced a famine in early life (8). It is interesting to speculate how famines and other natural calamities in different parts of the world in the last few hundred years could have sown the seeds of the modern day epidemics of NCDs.

David Barker and colleagues considered fetal growth and birth size as surrogates of fetal and maternal nutrition. They demonstrated an association between smaller size at birth and increased risk of diabetes, hypertension, and CVD (1). Smaller size was not due to premature delivery, but rather due to fetal growth restriction, which was ascribed to maternal undernutrition.

Fetuses appear to be highly sensitive to environmental changes that impact in utero conditions, particularly during critical stages of organ development. The in utero environment is influenced by the mother’s size, food and nutrient intake, metabolism, endocrine balance, stress, exposure to pollutants, and many other factors. In early
pregnancy the mother communicates with and nourishes the embryo directly through the contents of the uterine cavity and subsequently through the placental circulation. A blueprint for fetal growth and development is established early in pregnancy making periconceptional maternal nutrition of special importance. Pregnancy with a female child presents an even more interesting situation, since the uterine environment impacts the mother, the fetus, and the fetus’ developing oocytes: essentially three generations in a single pregnancy! Improving the intrauterine environment can therefore potentially improve the health of multiple generations. This makes a compelling case for the health practitioners and policymakers to target the health and nutrition of tomorrow’s mothers for the future health of the planet.

Since the original description of a low birth weight phenotype, further work has been done on the association between neonate dimensions and future outcomes like obesity and diabetes, including use of the fetal ponderal index (kg/m$^3$), fetal body composition, placental size and shape, and metabolic, endocrine, and epigenetic markers in the cord blood (9, 10). In the past, fetal growth disturbances were considered exclusive determinants of future health. However, gestational length is now also considered important, and early embryonic nutrition is known to influence both fetal growth and length of gestation (11).

**Nutrition and fetal programming**

The concept of nutritional fetal programming contributed to a paradigm shift in the field of nutrition, with a focus on intergenerational health and its molecular mechanisms, seen from a systems biology perspective. An exciting discovery was the demonstration that nutrients influence gene function by interacting with nuclear receptors and also through epigenetic mechanisms (12), both of which modulate gene expression. The resulting impact on multiple cellular processes, particularly during critical times in fetal development, could influence the structure and function of organs and systems, contributing to long term effects on health and disease susceptibility (programming) (13). Although the pregnancy and infancy periods are important (the “first 1,000 days”) (14), it is increasingly believed that the periconceptional period may be the most important (15).

Animal models of fetal programming frequently investigate the effect of maternal protein deficiency (16), but human data is sparse. A protein deficit leads to a shortage of amino acids, the building blocks of proteins, and can also disturb 1-carbon metabolism and DNA methylation, resulting in widespread downstream effects. Protein supplementation during pregnancy showed variable effects on fetal growth (17), indicating the need for further research. No specific role has been ascribed to carbohydrates and fats as macronutrients in fetal programming, but both are a major energy source and contribute to macrosomia in a diabetic pregnancy.

Micronutrients have emerged as important contributors to fetal programming. Methyl donors (folate, methionine, choline, and betaine, and co-factors vitamin B$_{12}$ and B$_6$) are of special interest because of their potential to influence DNA methylation (18). Both maternal folate (a B vitamin) and vitamin B$_{12}$ concentrations are associated with fetal growth (19, 20); higher folate is also associated with offspring adiposity and insulin resistance (21, 22), especially if vitamin B$_{12}$ is low (22). This suggests a need for balanced nutrition. These two vitamins also influence offspring neurodevelopment. Higher maternal homocysteine concentration (caused by vitamin B$_{12}$ and folate deficiency) is associated with fetal growth restriction. A maternal methylenetetrahydrofolate reductase (MTHFR) gene polymorphism that raises homocysteine concentrations also predicts fetal growth restriction, suggesting a causal role of
homocysteine (23). Studies in The Gambia demonstrated a seasonal pattern in methyl donor availability in the maternal bloodstream, which was reflected in different levels of DNA methylation in the cord blood (24). Similarly folic acid supplementation trials in pregnancy also influenced cord blood methylation (25). These human findings suggest a possible role for methyl donors in epigenetic fetal programming and later occurrence of NCDs. Animal models support such a role (26), but there is an urgent need for more human studies. Other micronutrients of interest in fetal programming include vitamin D, vitamin A, calcium, zinc, and omega-3 fatty acids.

We have proposed a "dual teratogenesis" construct to explain the U-shaped association between birth weight and diabetes (Figure 2) (27). Maternal-fetal undernutrition produces thin (poor lean mass) children with high adipose percentage and insulin resistance ("nutrient-mediated teratogenesis"). If these children continue to live in a deprived situation, they propagate this phenotype without overt diabetes. However, if they face overnutrition in postnatal life (urban migration), they are likely to develop obesity and hyperglycemia at a young age, and gestational diabetes in girls that propagates the obesity and diabetes phenotype ("fuel-mediated teratogenesis") (28). Rapidly transitioning countries like India seem to have both forms running simultaneously, feeding into an explosive epidemic of NCDs.

FIGURE 2. In undernourished populations, fetal undernutrition results in “thin-fat” babies who are insulin resistant. If postnatal nutrition is also low, they continue with the phenotype, and females can transmit this phenotype intergenerationally. If there is postnatal overnutrition, it can result in obesity and hyperglycemia, which can cause pregestational and gestational diabetes, promoting fetal macrosomia, and setting up an intergenerational cycle of obesity and hyperglycemia. In rapidly developing countries such as India, the two cycles operate simultaneously. This construct provides an explanation for the U-shaped association between birth weight and type 2 diabetes (T2D) (bottom graph) (adapted from 27).
Vitamin B<sub>12</sub> deficiency seems to be associated with both forms of teratogenesis in India (21, 29, 30).

**Conclusions**

It is high time that policymakers became more aware of the importance of maternal nutrition in improving the long-term health of populations. Hippocrates wrote "Let food be thy medicine and medicine be thy food." Modern science has extended this to intergenerational health. Ancient Indian physicians (Charak, Sushrut, and Vagbhat) understood that the transfer of nourishing maternal fluid to the fetus is important to attain proper body length, size, and health, and even provided dietary guidelines for both men and women planning to conceive. We would do well to develop similar evidence-based guidelines to improve fetal programming.

**References**


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Fetal and early childhood undernutrition, mortality, and lifelong health

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Child undernutrition is a major public health challenge, estimated to be responsible for 2.2 million annual deaths worldwide of children under the age of 5, although full implementation of available nutrition interventions could prevent more than one-third of these deaths (7). Interventions to improve breast-feeding and complementary feeding are estimated to be the first and third most effective preventive interventions against child mortality—the second being the use of insecticide-treated bed nets to protect against malaria (2). Improved breast-feeding and other nutritional interventions aimed at children under 5 and pregnant women have substantial benefits beyond affecting mortality, including improvements in intelligence quotient (IQ) and lower risks of some noncommunicable diseases (NCDs) (3), which collectively cause 63% of deaths globally (4). Further, improved breast-feeding also has benefits in high-income countries: The social costs of low breast-feeding rates in the United States alone were recently estimated at $13 billion annually (5).

Child undernutrition is a broad and complex phenomenon, encompassing fetal undernutrition; insufficient breast-feeding; and complementary feeding of diets low in energy-dense foods, essential fatty acids, and micronutrients. The effects of undernutrition include low birth weight and deficits in height and weight, as well as physiological outcomes later in life. The importance of these factors prompted U.S. Secretary of State Hillary Clinton to describe the benefits of improved nutrition in utero and during the first 24 months of life as providing a valuable “1000 day window of opportunity” for lifelong health and development (6).

At the risk of oversimplifying the topic, we review the recent and growing evidence of benefits of early nutrition, particularly breast-feeding, on child mortality and maternal and child health outcomes. We endeavor to distinguish between effects reported in low- and high-income countries, as these effects and the success of interventions may differ with diet and general sanitary conditions. Our review covers research in low- and high-income countries, including observational, case control, prospective cohort, and randomized studies. Our survey indicates there is credible evidence that improved population coverage of child nutrition interventions, particularly related to breast-feeding and complementary feeding, could provide large benefits in absolute terms and that these measures could do so at exceptionally low cost. However, public health funding for child nutrition research and programs is still relatively low compared with that for other life-saving child health interventions (7).

Here, we present evidence for benefits, an economic rationale for government intervention in breast-feeding, and a review of breast-feeding practices and policies. The rest of this paper addresses the early nutritional origins of disease, effective nutrition interventions in the first 1000 days, breast-feeding and NCD risk, the economic rationale for breast-feeding promotion, data on current breast-feeding and complementary feeding practices, and, finally, conclusions.

### Early nutritional origins of disease

The past few decades have seen an explosion of research suggesting that nutrition insults during fetal life have surprising and long-lasting ramifications for health (8, 9). Analysis of such effects is complicated by the lack of accepted measures of in utero exposure,

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**Table 1.** Breast-feeding and selected maternal health outcomes. CI, confidence interval. A person-year is the sum of the number of years that each study participant’s health condition was observed.

<table>
<thead>
<tr>
<th>Outcomes</th>
<th>Measure of breast-feeding</th>
<th>Effect size</th>
<th>Notes</th>
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<tbody>
<tr>
<td>Ovarian cancer</td>
<td>Length of breast-feeding</td>
<td>Reduced risk of ovarian cancer by 28% for each year of breast-feeding</td>
<td>Meta-analysis of nine studies with 4387 cancer ovarian cancer cases and 10,574 controls (32)</td>
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<td>(odds ratio: 0.72; 95% CI: 0.54 to 0.97)</td>
<td>First meta-analysis included 45 studies conducted through 2001; second meta-analysis included 23 studies published between 1980 and 1998 (32)</td>
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<tr>
<td>Breast cancer</td>
<td>Length of breast-feeding</td>
<td>Reduced risk of breast cancer by 4.3% for each year of breast-feeding in first analysis; reduced risk of breast cancer by 28% for each year or more of breast-feeding in second analysis</td>
<td>Two cohorts from a high-quality longitudinal study of 150,000 parous women in the U.S. (32)</td>
</tr>
<tr>
<td>Type 2 diabetes</td>
<td>Length of breast-feeding</td>
<td>Reduced diabetes risk by 4%; 95% CI: 1 to 9% per year of breast-feeding in first cohort and 12%; CI: 6 to 18% in second cohort</td>
<td>55,836 parous women in the U.S., reported 8861 cases during 660,880 person-years of observations (30)</td>
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<tr>
<td>Hypertension</td>
<td>Never breast-fed versus</td>
<td>Increased risk of hypertension by 29% (hazard ratio: 1.29; 95% CI: 1.20 to 1.40)</td>
<td>Two cohorts from a high-quality longitudinal study of 150,000 parous women in the U.S. (32)</td>
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<td></td>
<td>exclusively breast-fed</td>
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<td>first child for ≥6 months</td>
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the difficulty separating in utero exposure from exposure during infancy or early childhood, and the possibility of effects sufficiently severe to increase perinatal mortality, thus masking later adverse effects (10). Researchers have addressed these complications by focusing on "natural experiments" such as the Dutch Hunger Winter (resulting from severe wartime food shortages during the winter of 1944–1945) and religious fasts—episodes for which earlier or later cohorts provide suitable controls.

Effects of prenatal exposure to the Dutch Hunger Winter include obesity among 19-year-old men, fat deposition for women, schizophrenia, and elevated blood pressure (10). Prenatal exposure to daytime fasting during Ramadan has been reported to increase the likelihood of adult disability by more than 20% among Iraqis and Uganda’s Muslims, with substantially larger effects for mental and learning disabilities (10). One study considered effects of dietary supplementation with iodine during pregnancy in Tanzania—iodine deficiencies can cause low IQ score. Before the advent of iodized salt, maternal iodine deficiency was the leading preventable cause of mental retardation globally. After accounting for differences in uptake among families, girls who received iodine supplementation in utero were found to have had about an extra 6 months of schooling relative to siblings, even though their health was apparently unaffected (11).

All of these estimates should be seen as illustrative of how nutrition in utero affects long-term health and even schooling, rather than as concrete, quantitative estimates. One reason for this caution is that the biological effects of in utero and early childhood nutritional insults depend on their precise nature, severity, and timing during development. In addition, the effects also probably vary with later diet, physical activity, and genetic predisposition. Another reason for caution is that nonhealth outcomes, such as years of schooling, also depend on how families treat children who may be subtly different, and this probably varies with differences in culture or economic opportunities. Regardless, a growing amount of literature shows that fetal undernutrition, as reflected in size at birth, has been associated with a host of chronic diseases later in life, including coronary heart disease, diabetes, and hypertension (16). Such risks are exacerbated when infants grow up in environments where metabolic disorders are prevalent.

Ongoing prospective cohort studies in Brazil, Guatemala, India, the Philippines, and South Africa show that size at birth and accelerated weight gain after 46 months of life is related to insulin resistance (17), whereas greater weight gain during the first 5 years is associated with elevated blood pressure (12). These damaging effects are more pronounced if children become overweight during later childhood and adolescence. The damaging effects of undernutrition are associated with a wide range of lifetime prospects. For example, among Guatemalan boys living in villages where severe stunting was prevalent, random assignment of infants to high-quality dietary supplementation in the first 2 years of life led to a 46% increase in average wages in adulthood (14). Furthermore, women who were undernourished as children tend to have underweight babies, illustrating intergenerational effects of poor nutrition (15).

Interventions in the first 1000 days

A wide variety of policy interventions affecting nutrition in the first 1000 days of life can have long-lasting effects on health. Interventions to prevent child mortality, as highlighted in a Lancet series on maternal and child undernutrition in low-income countries, include breast-feeding and complementary-feeding counseling, as well as food supplements (when necessary) in children 6 to 24 months of age (16). Providing vitamin A and zinc supplements, ensuring universal salt iodization, and timely treatment of severe acute malnutrition are all interventions known to be effective in reducing child mortality (15). Iron supplements are also recommended, but not where malaria is prevalent because of the risk that iron supplements may increase mortality by increasing vulnerability to infections (17).

An important attribute of breast-feeding is that it enhances a child’s IQ, according to numerous studies in high- and low-income countries. A randomized, though blinded, trial showed that breast-feeding promotion raised IQ six points (18); other studies show gains more on the order of one to three points. Regardless of the exact number, these are large gains, comparable to the well-established effects of eliminating lead from gasoline (19). Analyses by the U.S. Environmental Protection Agency (EPA) suggest that an increase of one point in an individual’s IQ increases the present value of lifetime earnings by between 1.8 and 2.4%. Using data on median earnings of U.S. workers and assuming a discount rate of 3%, the EPA calculates the gain in net earnings from an increase of one IQ point to range from $8760 to $12,512 in 2006 U.S. dollars (20). To our knowledge, these estimates have not been included in economic studies of breast-feeding. Because IQ gains are expected in all breast-fed infants, IQ-related benefits appear sufficiently large to substantially improve the cost-effectiveness of breast-feeding interventions relative to other public health measures.

Maternal health matters too, not just intrinsically, but because mothers as the primary care givers for their children need to be physically and mentally healthy to provide adequate care. Indeed, maternal death is a risk factor for infant mortality. Anemia during pregnancy increases a woman’s risk of death from blood loss during delivery (1), and high-quality evidence supports the value of providing iron folate and multiple micronutrient supplements to reduce maternal anemia (16).

In addition, breast-feeding offers substantial benefits to mothers and their families because it delays the return of ovulation and menses, thereby extending the interval between pregnancies. Less frequent pregnancies reduce neonatal, infant, and child mortality (21) and undernutrition (22). Exclusive, on-demand breast-feeding during the first 6 months after giving birth is as effective at preventing pregnancy as condoms, diaphragms, and oral contraceptives (23). After 6 months, breast-feeding still has substantial contraceptive effects, which are particularly important as the use of active birth-control methods is still low in many countries, particularly in Africa. Nationally representative data on married women of reproductive age in 30 African countries between 2000 and 2012 show that, in more than half of these countries, less than one woman in five used contraceptives. Breast-feeding at current levels, compared with no breast-feeding, is estimated to avert 53 million births per year (24). Using the same data, we estimate that breast-feeding at global levels consistent with the World Health Organization (WHO)’s recommendations would further reduce births by another 12 million annually.

In addition to other benefits, improved basic sanitation (such as hand-washing and
access to toilet facilities) can improve child nutrition in low-income countries by reducing intestinal diseases that reduce nutrient absorption and cause loss of appetite (25). A robust body of literature illustrates that the effects of acute illness, particularly diarrhea, in early childhood interact synergistically with poor diet to cause childhood stunting (26). Evidence is also accumulating to show that nutrition-sensitive agriculture and social protection interventions can positively affect child nutrition (27, 28).

Breast-feeding and NCD risk
Emerging data show that breast-feeding plays a role in reducing NCDs, which in 2010 were estimated to cost $863 billion globally in medical expenses and lost productivity (29); morbidity and mortality rates from NCDs surpass those from communicable diseases in every region but Africa. Furthermore, women who breast-feed reduce their risk of key NCDs, according to recent observational studies. These women experience lower rates of ovarian and premenopausal breast cancer and type 2 diabetes (Table 1). They also appear to have lower risk of some adverse cardiovascular outcomes (30).

Furthermore, data are beginning to reveal the effects of early childhood feeding patterns on NCD risk to children later in life (31). Systematic reviews of available evidence from low- and high-income countries suggest that children who were breast-fed had lower mean blood pressure and total cholesterol (3), as well as fewer cases of type 2 diabetes (3, 32). However, a more recent study from five prospective cohorts in low- and middle-income countries failed to substantiate these effects (33). Still, the role of different patterns of complementary feeding in relation to risk of NCDs is virtually unexplored (34). Unlike breast milk, which evidence has proven to be superior to other foods for infants, no set of complementary foods or feeding practices is shown to be of better quality, either for healthy growth in the short term or for lower NCD risk in the long term. However, exposure to high levels of salt early in life may damage developing kidneys, predisposing an individual to subsequent high blood pressure (35). A growing amount of literature suggests that gut microflora may develop differently (36) in response to early introduction of different complementary foods, with potential long-term implications for the host’s overall health (36).

Breast-feeding promotion: The economic rationale
Among the causes of the global disease burden, communicable diseases have long been the targets of choice. The rationale for intervention is stronger with communicable diseases because of the risks of contagion. Often unrecognized, however, is a comparably strong economic rationale that exists for breast-feeding.

In a 1970 paper that later earned him a Nobel Prize, George Akerlof showed that lower-quality products can displace higher-quality products in instances where buyers cannot discern quality (37). Such instances of information asymmetry have long been recognized as market failures by the U.S. Office of Management and Budget (38). Breast milk is an example of a higher-quality good whose superiority relative to infant formula is very difficult for mothers to fully perceive. As a nonmarket good, breast milk defies conventional private solutions to information asymmetry problems, such as product warranties or investments in brand-name reputations. Breast-feeding requires successful initiation at birth, when mothers are vulnerable to influence from medical staff or family and ill-placed to make independent decisions. In addition, early use of infant formula hinders later breast-feeding. For mothers who study or work outside the home, breast-feeding requires a place and time for expression and storage of milk, which may be difficult arrangements to negotiate individually with schools or employers. Hence, there is a fundamental and legitimate need for coordinated action to protect breast-feeding, and history reflects recognition of this need.

In the late 1970s, compelling accounts emerged of infants who became acutely malnourished or died from contaminated or diluted formula after free samples were given to their mothers (39). To protect breast-feeding, the World Health Assembly (WHA) adopted the International Code of Marketing of Breast-milk Substitutes in 1981 (40). The code provides guidelines on marketing strategies associated with increased formula feeding, such as direct promotion to the public, free supplies to mothers and health care institutions, and the use of baby images on labels that idealize bottle-feeding. A total of 12 subsequent WHA resolutions—the most recent in 2010—have strengthened the original guidance; nonetheless, violations continue (41). The 1990 Innocenti Declaration endorsed by the WHA set operational targets that governments should achieve, and in 1991, WHO and United Nations Children’s Fund (UNICEF) launched the Baby Friendly Hospital Initiative to promote hospital environments conducive to breast-feeding. Elements of successful breast-feeding promotion strategies are well documented (42).

In 1996, breast-feeding promotion was estimated to be exceptionally cost-effective: $150 for each diarrheal death prevented in Latin America (43). This estimate placed breast-feeding promotion among the most cost-effective interventions for child survival, equal to other high-impact interventions such as immunizations. However, this assessment does not include the gains in IQ and reductions in NCDs, which would make estimates of cost-effectiveness substantially more attractive.

The revolution in information technology could further contribute to efficiencies in breast-feeding promotion. Timely delivery of information that is culturally sensitive, specific to the issue at hand, and authoritative is highly effective in getting mothers to breast-feed exclusively (44). Cell phones or smart phones have been effectively used to communicate health messages in HIV treatment (45) but have rarely been used in programs to promote breast-feeding or complementary feeding. Innovative use of these technologies could greatly improve the cost-effectiveness of child nutrition programs.

Of late, funding for breast-feeding promotion has declined (46). U.S. Agency for

Fig. 2. (A and B) Percentage of infants and children meeting recommended breast-feeding and complementary feeding practices. Data are from nationally representative surveys conducted in 46 low- and middle-income countries between 2002 and 2008 and represent 82, 58, and 22% of the population of children younger than 5 years of age in Africa, Asia, and Latin America/the Caribbean, respectively.

PERSPECTIVE

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International Development (USAID) global spending on child nutrition, of which breastfeeding promotion was an important component, declined from $16.6 million in 1999 to $13.3 million in 2003. Between 1999 and 2005, investment in breastfeeding in USAID’s flagship maternal and child nutrition project declined from $4.9 million to $2.3 million, while project expenditures for prevention of mother-to-child transmission of HIV increased, reflecting the seismic shift in global funding priorities related to the HIV/AIDS epidemic. Donors other than USAID also cut funding (46).

Data from African, Asian, and Latin American/Caribbean countries suggest that supportive policies and programs can markedly affect exclusive breastfeeding percentages (Fig. 1). In 1993, Ghana and nearby Mali had reasonably similar rates (~8%) of exclusive breastfeeding. Yet by 2005, the rates differed by 15 percentage points, despite improvement in both countries. Cambodia achieved a phenomenal gain in exclusive breastfeeding rates of nearly 50 percentage points in 5 years, whereas in Bangladesh, the rate slipped slightly from 46% over 15 years. In Brazil, exclusive breastfeeding increased 40 percentage points, from 3 to 43% between 1986 and 2006, but over roughly the same period in Mexico, the exclusive breastfeeding rate decreased by 5 percentage points. For Brazil, a 20-year chronology links key legislative, policy, and programmatic measures with improved breastfeeding practices (47). Thus, government policy and public health measures appear capable of effecting large gains in breastfeeding in some countries, even given concurrent increases in urbanization, female education, and employment that are traditionally associated with declines in breastfeeding rates.

**Current breastfeeding and complementary feeding practices in selected low- and middle-income countries**

A big gap still separates current practices from accepted breastfeeding recommendations in low- and middle-income countries (Fig. 2) (48). WHO recommends 6 months of breastfeeding in low- and middle-income countries are put to the breast within 1 hour of birth.

Global practices in complementary feeding in low- and middle-income countries are poor (Fig. 2) (48). Only half of children 6 to 24 months of age met the recommended minimum daily numbers of meals, less than one-third met the minimum criteria for daily dietary diversity, and only one in five breastfed children satisfied the criteria for minimum acceptable daily diet. Moreover, there are wide differences among countries with relatively similar income levels. In Ethiopia, which had a gross domestic product (GDP) of $1100 in 2011, only 3.9% of children 6 to 24 months of age met the minimum standard of daily dietary diversity. In contrast, in Uganda, with an estimated GDP of $1300 for the same year, 23.6% of children in the same age group satisfied this criteria (51). Low national income, though important, is not the only impediment to improved complementary feeding.

**Conclusions**

The prenatal period and the first 24 months of life provide a 1000-day window in which sound nutrition, especially adherence to recommended breastfeeding and complementary feeding practices, can improve not only the health of vulnerable infants and young children, but also the trajectory of aspects of their well-being and the health of their mothers. However, a large gap between current and best practices exists. Research on how to cost-effectively improve the coverage of existing nutrition interventions is needed to help accelerate their health impacts (7).

Research is also needed to better understand the biological mechanisms through which the effects of improved breastfeeding occur, because randomization in breastfeeding studies is nearly impossible to achieve. Most evidence derives from observational studies whose interpretations are complicated by self-selection, measurement errors, and residual confounding (3). Knowledge of the underlying metabolic pathways through which breast-feeding or breast milk affects specific health outcomes, such as the role of human milk serum adiponectin exposure and early childhood weight gain (52) and how human milk and complementary foods affect the gut microbiome, will improve interpretation of epidemiological studies. Acquiring a deeper understanding of the most common breastfeeding and complementary feeding difficulties and identifying the most effective strategies to overcome these difficulties is essential. Surveys, randomized interventions, and systems analyses are needed to explore the functioning of health care systems and the behavior of health professionals in relation to the persistence of impediments to better feeding practices. Both basic and applied research are required to develop an evidence-based set of policies and programs to improve complementary feeding. Finally, research is needed to measure the population risk attributable to suboptimal feeding practices and child nutrition, as well as the costs in medical treatment and lost productivity.

The beneficial effects on child mortality and IQ and on maternal NCD risks of improved nutrition during the prenatal period and first 2 years of life appear large compared with other public health interventions. Because breastfeeding promotion provides the greatest short-term benefit for children living in poor environments, investments in breastfeeding protection and promotion will also improve global health equity. Nonetheless, funding for research and greater use of existing effective interventions is low compared with other life-saving child health interventions.

**REFERENCES AND NOTES**


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Worldwide undernutrition in older adults: Too often unrecognized and untreated

Jean-Pierre Michel

Undernutrition is a specific form of malnutrition in which energy intake falls short of energy expenditure, creating an energy deficit and is characterized by unintentional weight loss, low body mass index, and/or insufficient food intake. In patients identified as moderately to severely malnourished, proper nutritional assessment, clinical diagnosis, and treatment are vital. Ongoing medical conditions, disability, poor life habits, and altered social conditions can contribute to undernutrition, which may be relieved by appropriate treatment or counseling. Whatever the clinical situation, nutrition plays a crucial role, facilitating health recovery after an acute medical or surgical event, and it should be an integral component in the treatment of chronic diseases so as to reduce complications from undernutrition. However, undernutrition is rarely adequately treated in hospitalized older adults. When dietary advice and food fortification fail to normalize nutritional status, oral nutritional supplements should be used to supplement food intake. Training of health care professionals and routine practices in health care institutions need to be improved since there are numerous clinical and economic benefits to adequate prevention and treatment of undernutrition.

The terms malnutrition and undernutrition are often used indiscriminately, without sufficient attention to their true meanings. Malnutrition covers four different nutritional problems: excessive nutritional intake (overweight and obesity), unbalanced diet (economic-, age-, disease-, or treatment-related changes in smell, taste, and cultural nutritional habits), specific nutritional deficit(s) (e.g., vitamin and oligo-element deficiencies), and insufficient nutritional intake regardless of etiologies (e.g., insufficient protein-energy intake, specifically called undernutrition) (1). Undernutrition, which corresponds mainly to protein undernutrition, occurs specifically when energy intake falls short of energy expenditure (2).

Today, undernutrition in aged adults is not well recognized and often remains untreated, an issue that will be addressed further below.

Undernutrition too often goes unrecognized

The concept of undernutrition, and the risk thereof, is based on unintentional weight loss, low body mass index (BMI), and/or insufficient food intake.

Unintentional weight loss

Classically, a weight loss of 5% in one month or 10% in six months corresponds to undernutrition, while a weight loss of >10% in one month and >15% in six months defines severe undernutrition. Since aged adults often do not accurately recall their weight over time, the help of caregivers is frequently needed to estimate approximate weight loss. Indeed, any unintentional weight loss needs to be carefully assessed and tracked.

Body mass index

BMI is calculated as body weight in kilograms divided by height in meters squared (3). According the World Health Organization (WHO), there is an internationally accepted scale for classifying BMI (4). However, the use of BMI to determine undernutrition presents several limitations. For example, the height of older persons decreases with age, causing the BMI to be overestimated. Additionally, there is some difficulty in applying the international BMI scale to Asian populations (5, 6).

Insufficient food intake

The causes of undernutrition can be complex, a common factor being illness or injury, which can interfere with adequate food intake, absorption, and metabolism. Undernutrition has been linked to infection-related changes in metabolism, disease-specific catabolism, appetite loss, swallowing problems, absorption and digestion disorders, and gastrointestinal symptoms of feeding intolerance (7).

If any one of these three undernutrition risks exists, it is necessary to perform nutritional screenings. In case of any abnormality, nutritional assessment followed by a medical investigation should be mandatory to identify the cause(s) of undernutrition, followed by nutritional intervention, monitoring, and supervision, if necessary (8).

An effective screening tool should be simple to use, quick, reliable, sensitive, and provide reproducible results in order to identify undernourished older adults. More than 20 tools are currently available, among which the Determine nutritional screening tool, the Mini Nutritional Assessment (MNA), the Malnutrition Universal Screening Tool (MUST), and the Malnutrition Screening Tool (MST) are the most frequently used (9). These tools are quite similar to one another and the choice of which one to use depends primarily on the physician’s preference together with how well the tool is accepted by the medical team members familiar with the country’s cultural and religious background.

In Singapore, application of the Determine tool among 2,605 community-dwelling (those living outside of assisted living or nursing homes) Chinese-origin subjects aged between 55 and 99 years (mean 66.0 ± 7.7) revealed that 25.5% and 4.6% of the population studied were moderately or severely malnourished, respectively (10). These findings agree with those obtained in Japan (11), Turkey (12), and multiple European countries (13, 14).

When admitted to a hospital, patients aged over 65 years old appeared to be more malnourished than their young counterparts (15). In China, on Nutrition day in 2010, 42.5% of patients (mean age of 50.6 ± 18.5 years) admitted were found to be undernourished (16), while in Australia, analysis of admissions to a rehabilitation ward found 33.0% and 51.5% of patients were classified as malnourished or at nutritional risk, respectively (17).

Undernutrition can cause a range of adverse outcomes. Some of these include:

- A decrease in lean body mass, primarily skeletal muscle mass, corresponding to sarcopenia. Sarcopenia was recently defined as
a decrease in muscle mass and muscle strength or function leading to adverse outcomes such as falls, inability to perform activities of daily living, and infections (18)
• A decrease in immunocompetence, mental state, and treatment tolerance, with modification of gastrointestinal, cardiovascular, renal, and respiratory functions, slowing down the recovery process and altering quality of life (19, 20)
• An increase in rate, duration, and severity of infections, overall complication rates, hard-to-heal wounds and pressure ulcers, immobility, risk of falling, and need for help performing daily activities, as well as increased morbidity and mortality (21, 22).

The impact of bed rest should also be highlighted. After three days of bed rest, elderly in-patients lose approximately one kilogram of muscle in their lower limbs (23), contributing to the weight loss often noted when they are discharged. In fact, a comparison of undernutrition rates at hospital admission and discharge has shown wide differences: 8.2% vs. 11% for surgical patients in China (24), and 12% vs. 20% for stroke patients in Korea (25). A prospective matched case control study in Singapore demonstrated that malnutrition was a significant predictor of death in patients aged 18 to 74 years [odds ratio of 4.4, 95% confidence interval (3.3-6.0), P <0.0001] (22). Finally, the hospital resources required to treat undernutrition represent one third of total hospital costs (26).

Undernutrition too often goes untreated

A more in-depth nutritional assessment following nutritional screening during hospital admission is essential for those patients considered to be at risk. One of the most convenient tools for this is the Subjective Global Assessment (SGA) (27). The SGA classifies patients in various ranges as well- to normally-nourished, mildly to moderately malnourished, or severely malnourished. For patients who were scored as moderately or severely malnourished, clinical diagnosis and treatment constitute the most important part of an intervention program. The following factors should be taken into account when identifying appropriate treatment measures for these patients:
• Oral and dental problems, swallowing disturbances, and age-related anorexia or special nutritional requirements
• Specific diseases or polypathology and polypharmacy, restrictive therapeutic diets, and undiagnosed or uncontrolled pain as well as frailty, mobility disorders, or any cognitive, mood, or mental disturbances
• Limited food preferences, alcohol abuse, or physical inactivity
• Poverty, loneliness, or social isolation as well as living in unfamiliar surroundings, or a new cultural or religious environment that limits access to preferred foods.

No matter the clinical situation, proper nutrition can play a crucial role in facilitating health recovery after an acute medical or surgical event. Nutrition needs to be an integral component of the treatment of chronic diseases as it can play a beneficial part in decreasing complications (28).

If dietary advice and food fortification (such as snacks) are not sufficient to meet nutritional requirements, oral nutritional supplements (ONS) should be used to supplement food intake. These are ready-made, energy dense (between 1 and 2.4 kcal/mL) nutritional supplements containing both macronutrients (protein, carbohydrate, and fat) and micronutrients (vitamins, minerals, and trace elements). Before starting nutritional supplementation, it is important that treatment goals are clearly determined, including the timing of supplement delivery and specific formula (selection of ingredients, combination of components, and selection of flavors) (29). Many products are conveniently available in liquid, semi-liquid, or powder formats, and in a wide variety of flavors.

The use of ONS in malnourished patients presents several advantages that are associated with positive outcomes. In hospitalized patients, ONS have been shown not to reduce food intake and, in post-surgical patients, there is even evidence that they significantly stimulate appetite and food intake (30), particularly protein intake (31). However, after similar periods of starvation or poor nutrition, aged adults may require a longer period of renutrition to recover their previous weight than their younger counterparts (32). This means that nutritional supplementation with ONS may require continued therapy for at least four to six weeks before a clinical benefit can be seen. Further, ONS significantly increases energy intake (33), prevents weight loss (even in community-dwelling patients), and increases weight gain among hospital in-patients (34). ONS also significantly decreases hospital complications such as pressure ulcers, operative site and catheter infections, and cross infection (35, 36) as well as in-patient mortality (37). Dietary supplementation with ONS, and more specifically β-hydroxy β-methyl butyrate (HMB), significantly reduces the loss of lean body mass after 10 days of bed rest, while HMB coupled with physical exercise increases lean body mass under the same bed rest conditions (38). Finally, ONS treatment started during a hospital stay and continued at home after discharge enhances independence and quality of daily life (39).

A systematic review (which included a meta-analysis of individual randomized controlled trials) concluded that, overall, ONS can be regarded as a safe intervention without any significant adverse effects. While there was some reference to minor gastrointestinal symptoms, the majority of trials do not assess gastrointestinal tolerance (40).

Conclusions

This paper presents strong evidence that among community-dwelling and hospitalized subjects, undernutrition is not sufficiently well recognized or treated. Significant benefits in terms of quality of care and reduction in the overall cost of care can be obtained by providing supplemental nutrition that counteracts the protein-energy deficit of undernourished patients on bed rest. The suboptimal clinical attitude found in many hospitals can be explained by a lack of robust nutritional protocols for screening, a deficit in knowledge about nutrition due to inadequate training of health care professionals, and poor documentation of nutrition-related information, all of which result in inadequate nutritional care planning and monitoring. It is essential to counteract this dearth of knowledge and clinical skills, and educate health authorities and institution managers about the clinical and economic benefits that can result from better diagnosis and treatment of undernutrition.

References
Feeding them right to improve outcomes — it takes the whole team

Kelly A. Tappende

Amputation of the wrong leg. Treatment of the wrong patient. Feeding into the wrong tube. Medical errors are feared by patients, physicians, and administrators alike. However, not all medical errors are as shocking as those that make the nightly news. In fact, far more prevalent—estimated to account for 17% of preventable errors in hospitalized patients—are diagnostic errors that result in incorrect or missed treatment (1).

Malnutrition is a commonly missed diagnosis with big implications. Conservative estimates indicate that 30%-50% of hospitalized patients are malnourished upon admission (2), yet 2010 data indicate that only 3.2% of patients discharged from U.S. hospitals had this diagnosis (3). Failure to identify and treat malnutrition is a significant problem because patients with malnutrition do less well—they are at increased risk for complications, longer length of stay, and readmission to hospital (2). Clearly, we need to do better.

Why is malnutrition so often overlooked by medical professionals specifically trained to identify and treat patients with a long and complicated list of health problems? The reasons are multifold; however, the lack of courses about nutrition in medical education must certainly play a role. In 2009, only 25% of medical schools surveyed required courses dedicated to nutrition (4). Overall, students received less than 20 contact hours of nutrition instruction during medical school. Not only does this quantity of nutrition exposure fall short of the minimum requirement endorsed by the National Academy of Sciences, but this number has also changed very little since 1980, despite recognition of its inadequacy.

Regarding malnutrition specifically, a recent survey indicates that 87% of hospital-based physicians in Canada believe that optimal care includes nutrition assessment upon admission to hospital, but only a third indicate this is current practice. Respondents indicated the wide gap between perceived ideal management of hospital-related malnutrition and current practices, related to limited nutrition knowledge among physicians and inadequate utilization of registered dietitians/nutritionists (RDNs). Indeed, only 26% of individuals identified as being malnourished were seen by a dietetic professional in 2009, despite recognition of its inadequacy (5). Overall, physicians and inadequate utilization of registered dietitians/nutritionists (RDNs). Indeed, only 26% of individuals identified as being malnourished were seen by a dietetic professional in 2009, despite recognition of its inadequacy (5). Overall, physicians and administrators alike. However, not all medical errors are as shocking as those that make the nightly news. In fact, far more prevalent—estimated to account for 17% of preventable errors in hospitalized patients—are diagnostic errors that result in incorrect or missed treatment (1). Malnutrition is a commonly missed diagnosis with big implications. Conservative estimates indicate that 30%-50% of hospitalized patients are malnourished upon admission (2), yet 2010 data indicate that only 3.2% of patients discharged from U.S. hospitals had this diagnosis (3). Failure to identify and treat malnutrition is a significant problem because patients with malnutrition do less well—they are at increased risk for complications, longer length of stay, and readmission to hospital (2). Clearly, we need to do better.

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The need for nutrition expertise is a common theme related

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5. Failure to identify and treat malnutrition is a significant problem because patients with malnutrition do less well—they are at increased risk for complications, longer length of stay, and readmission to hospital (2). Clearly, we need to do better.
to malnutrition diagnosis failure. RDNs are professionals with extensive nutrition knowledge who are trained to identify patients with malnutrition and provide scientifically-based nutrition interventions. However, many institutions lack adequate RDN staffing to properly address all patients and RDN recommendations are poorly implemented. Recognizing these barriers, in May 2014 the U.S. Centers for Medicare and Medicaid Services (CMS) granted long-awaited privileges allowing hospital RDNs to independently order therapeutic diets and laboratory tests essential to the nutrition care and monitoring of patients under their care. This new ruling is expecting to improve quality of care by increasing efficiency, and save CMS $459 million per year.

Streamlining malnutrition recognition and intervention by providing RDN-ordering authority is only one step toward solving the problem of malnutrition. Barriers related to effective functioning of the health care team must be broken down. Optimal nutrition care requires physicians, nurses, RDNs, and other health care practitioners to work together, each within their scope of practice, to evoke meaningful improvements in nutrition care. Take as an example an elderly grandmother admitted to hospital with dementia and poor regulation of diabetes on a Wednesday morning last summer. Though very weak and having trouble walking on her own, a cursory assessment indicated that she was a little overweight so a nutrition concern was ruled out. A nutrition screen following admission—specifically designed to identify patients with a possible nutrition concern—was never done. Further procedures proceeded routinely. Psychology and endocrinology consultations were ordered, diabetic meals were delivered to the room, and loving family members sat with "mother" each and every day. It wasn't until the following Monday when the diabetes diagnosis spurred the attention of the RDN (who isn't scheduled to work on weekends). Nutrition assessment clearly revealed a moderately malnourished patient—"mother" had lost 20 pounds in the last three months, lost all interest in her meals, had peripheral muscle atrophy and diminished strength, had false teeth that were cracked and not fitting properly, and anemia due to a vitamin B₁₂ deficiency that provided the basis for her dementia. The RDN documented the diagnosis and intervention recommendations in the electronic medical record (EMR) to alert the physician to the need for nutrition intervention. However, nothing was done for "mother" until the RDN physically tracked down the physician three days later because nutrition notes aren't integrated in a prominent position within the EMR and the RDN is not included within the daily huddles discussing each patient. In this instance, over 30 meal trays were taken in and out of "mother's" room, relatively untouched, without a coordinated process to provide accessible and nutritious food to a patient with a nutrition-related diagnosis.

In "mother's" case, there are multiple points of failure. First, visual nutrition screening is not adequate. Our hospitals need to adopt policies and procedures where validated nutrition screens are applied to each and every patient upon admission. Many screening tools are available that can be administered easily by any staff member by asking two simple yes/no questions. Until nutrition screening is properly applied to all patients, many of those with undiagnosed malnutrition will go untreated. Had the patient in the example above been properly screened, the RDN would have been alerted shortly after admission, rather than stumbling upon a high nutrition risk diagnosis by being proactive the following week.

Second, the RDN is indeed the nutrition expert. Their assessment does not replicate that conducted by other clinicians, but rather focuses on nutrition-relevant problems such as nutrient deficiencies and the inability to consume food due to dental issues. However, they are often overworked and not scheduled outside standard business hours. So RDNs must rely on nurses to be their "eyes and ears" on the ground.
to observe a patient’s food intake, tolerance to meals, and to reinforce the importance of good nutrition. Empowered nurses who felt responsible for the nutrition care of “mother” may have expressed concern after two or three untouched meal trays, rather than three dozen.

Third, nutrition care must be integrated as an essential part of patient care. The role that nutrition has on patient outcomes must be recognized by physicians, administrators, and other health care providers so that it can be prioritized. Nutrition should be discussed at daily rounds, integrated into a prominent part of the EMR, and routinely emphasized with patients and their caregivers. The scenario above is unfortunately far too common. At least one-third of patients admitted to hospital are malnourished, and another third will become malnourished during their hospital stay (2). And our collective failure to nourish these patients stems from multiple problems that will require the entire health care team to rectify.

Toward this end, the Alliance to Advance Patient Care was founded in 2013 as an interdisciplinary partnership among RDNs, nurses, physicians, and public health leaders dedicated to overcoming the large, hidden, and costly problem of hospital malnutrition. The Alliance published a pioneering Nutrition Care Model recommending interdisciplinary principles to address adult hospital malnutrition (Figure 1)(2). To facilitate adoption, these recommended principles are discussed within the disciplinary framework of the various health care professionals to demonstrate the necessity of all team members to the nutrition care process and provide relevant examples where specific actions are needed. Finally, the Alliance also launched a comprehensive website, www.malnutrition.com, as an authoritative resource on hospital malnutrition. The website makes available a practical toolkit with validated screening tools, feeding tips, fact sheets, case studies, patient discharge materials, and patient education handouts. The website further offers an evidence library of research on nutrition intervention in clinical settings, provides study overviews vetted by specialists in hospital-based malnutrition, and links to education material.

One does not need to be a nutrition expert to realize that nutrition is neither optional, nor an issue that can be put off for a couple of weeks until the patient is doing better. Indeed, one of the first things any mother will do in an effort to care for her sick child is whip up a batch of chicken noodle soup. Though the scenario is often far more complicated in hospitalized patients, we must ensure that nutrition is not overlooked, or even disregarded. Clinical protocols are often used as an effective tool to drive best practices within the health care setting. As such, institutions must adopt clinical protocols that will systematically identify patients who are malnourished or at risk, and promptly intervene. The interdisciplinary care plan proposed by the Alliance provides an algorithm to guide optimal nutrition care from hospital admission through post-discharge, and outlines specific actions needed by various hospital stakeholders, including administrators, nurses, physicians, and RDNs (2).

As part of health care reform, CMS uses “quality measures” as tools to clearly state expectations and quantify outcomes with the aim of making health care effective, safe, efficient, patient-centered, equitable, and timely. Given the impact of malnutrition on patient outcomes, resource use, and costs, it is time for quality measures focusing on nutrition. Recognizing the need for quality improvement regarding malnutrition care, the Academy of Nutrition and Dietetics and Avalere Health held a dialogue among experts that concluded that action is needed in the following areas (7):

1. **Nutrition care plan execution.**

   Though it seems unacceptable, nutrition care plans are poorly implemented for many of the reasons outlined above. To solve this problem, strong expectations must be in place that individualized, evidence-based nutrition care be provided to patients as an essential element of the overall care they receive.

2. **Hospital-acquired malnutrition defined as a never event.**

   In health care, a never event is that kind of mistake that should not ever happen. For example, performing surgery on the wrong body part is considered a never event. If inadequate nutrient provision resulting in malnutrition while a patient was in care at a health care facility were to achieve never event status, awareness and accountability for this issue would be increased. Until nutrition care is included on the list of issues by which hospitals are evaluated and reimbursed it will continue to be overlooked.

3. **Presence of EMR template to support nutrition care.**

   Contemporary EMRs are not just the venue for documentation and communication, but serve as an important hub to advance patient safety and quality improvements, achieve operational efficiencies and cost saving, and improve both patient and staff satisfaction. As such, nutrition needs to be thoroughly integrated into EMR platforms to strategically leverage this reality of current practice. Standardized nutrition nomenclature, integrated templates, and clinical decision support are an essential portal for integrating nutrition into patient care, but will also open the door to further data collection that is necessary for both efficacy and quality.

   As individuals, we have high expectations for our health care. We expect to be treated promptly. We expect to be safe. We expect the most advanced, science-based care. Why is it in 2014 that we need to explicitly state that we expect to be fed? Feeding patients is indeed an essential element of prompt, safe, and advanced, science-based care. Nutrition needs to be elevated; nutrition is a vital sign.

**References**

MALNUTRITION IS A GLOBAL PROBLEM WITH VERY SERIOUS CONSEQUENCES

Up to 50% of patients are already malnourished when admitted to the hospital, malnutrition is one of the main reasons for readmission, and the costs of hospital care can be up to three times greater for malnourished patients. There’s no doubt—the risks are costly both economically and socially.

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