Starting down the right path: nutrition connections with chronic diseases of later life[1–3]

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ABSTRACT

Thirty years have been added to the average life expectancy of Americans over the past century. It is a reasonable expectation that Americans will achieve an average life span of ≥100 y within this century. The most dramatic decreases in early-life and midlife mortality coincided with advances in medicine; curative medicine has played a lesser role. The aging of the population alone has already increased health care costs, and as we move toward even longer lives, these costs will likely increase even more. Therefore, establishing and safeguarding optimal health from early life must become increasingly important concerns for governments and health care providers if they are to allocate resources wisely and ensure and maintain a high quality of life in the population. A prevention-oriented, life cycle approach is critical to establishing and maintaining health throughout life. This approach can delay and compress morbidity and the social toll associated with chronic disease and disability for as long as possible into old age. Good evidence exists that early nutrition affects key risk factors for chronic degenerative diseases of middle and later life, such as osteoporosis and cardiovascular disease. The influence of nutrition on health status and morbidity supports primary, secondary, and tertiary prevention of disease and intervention strategies at each point in the process. The objective of such a prevention-oriented model is to enable people to live well for longer, while minimizing chronic disability. Starting down the right path with appropriate nutrition and staying on it by eating well are important components of healthy aging. *Am J Clin Nutr* 2006; 83(suppl):415S–20S.

KEY WORDS Nutrition, osteoporosis, cardiovascular disease, aging, compression of morbidity, nutrigenomics, disease prevention, CATCH, evidence-based practice

INTRODUCTION

Life expectancy at the turn of the 20th century in the United States was 49.24 y (1). Americans now live an average of 77.2 y, and those who are now 65 y old can expect to live an additional 18.1 y. Relatively healthy Americans who are currently aged 75 y may expect to live to an average of 86.5 y (2). The rise in life expectancy over the past century has been linear, with no indication of an imminent decline in the rate of increase (3). Therefore, it is reasonable to expect the average life span in the United States to reach or exceed 100 y in the 21st century. However, because the average age at chronic disease onset has not risen to the same extent as life expectancy, a typical American currently aged 75 y can look forward to only 4 more years of active health followed by >7 y of disability (2). If the age of chronic disease onset does not increase commensurate to the added years of life still to come, a growing number of centenarians will spend the last 2 decades of their lives living with the serious and debilitating consequences of chronic disease. This is not a future that anyone is happy to contemplate.

Nutrition has a major role in protecting health and slowing disease progression. Paradigms that promote the nutritional components of healthy aging are needed to increase the age of chronic degenerative disease onset and to maintain healthy, functional lives for as long as possible. That is, the goal, if possible, is to compress morbidity. How successful we are in doing it may ultimately determine the quality of life in very old age.

STARTING ON THE RIGHT PATH

An evidence-based, prevention-oriented, population-wide life cycle approach to preserving health includes strategies for both the general population and those at high risk of disease. The preventive approach identifies those who have markers of susceptibility but who do not yet have the disease and focuses on prevention. Keeping as many people as possible free of risk (primary prevention), keeping those already at risk at the lowest risk possible and delaying disease onset (secondary prevention), and treating those who are already diseased to mitigate disease progression (tertiary prevention) are all levels at which interventions can be made to prevent further morbidity. Prevention is the key to healthy living: starting life healthy, staying healthy, and maintaining the lowest risk throughout life. The high-risk approach focuses on those who already have the disease and treats them to prevent further morbidity. It, too, has a place, but the emphasis must be on prevention.

FOLIC ACID AND NEURAL TUBE DEFECTS: PRIMARY PREVENTION

The periconceptional use of folic acid to prevent neural tube defects (NTDs) is a good example of the importance of early

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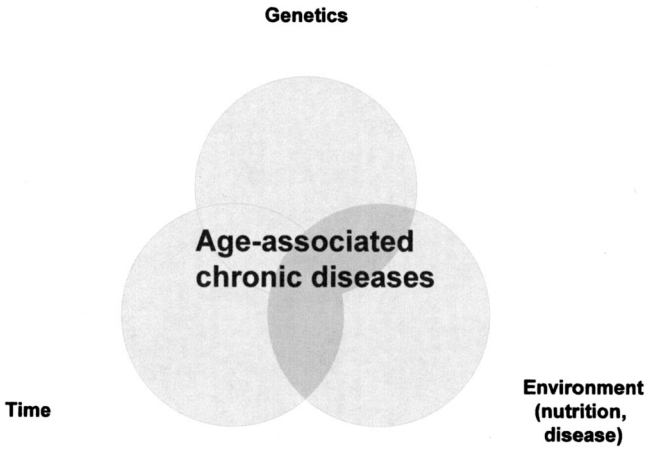

FIGURE 1. The life cycle approach to disease prevention, which highlights the interactions between genetics, environment, and the effects of time in considering how the development of age-associated chronic diseases may be influenced.

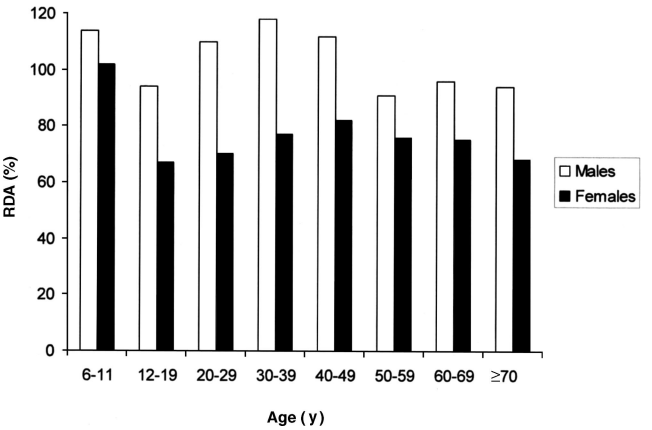

FIGURE 2. Mean calcium intakes as percentages of the 1989 Recommended Dietary Allowances (RDAs) by sex and age, 1994. Adapted from the US Department of Agriculture's 1994 Continuing Survey of Food Intakes by Individuals and 1994 Diet and Health Knowledge Survey (18). Mean calcium intakes in females were consistently below the RDA, particularly during adolescence when maximal calcium retention occurs.

nutrition, even before birth, playing a role as a factor governing future health. Randomized controlled trials and case-controlled studies of women with or without a prior pregnancy affected by NTD have shown that folic acid supplements during the periconceptual period significantly reduce the risk of further NTD-affected pregnancies (4–8).

For example, in a double-blind randomized controlled trial of the efficacy of daily periconceptional multivitamin-multimineral supplements containing 0.8 mg folic acid in 4753 women planning pregnancy, the prevalence of NTD was significantly lower in the supplemented group (0/2104 compared with 6/2052; $P = 0.02$) (4). In the international, multicenter British Medical Research Council trial, which involved nearly 1200 women at high risk because of a previously affected pregnancy, 4 mg folic acid daily from at least 1 mo before conception and through the first trimester reduced the risk of recurrence of NTD from 3.5% to 1.0%, for a relative risk reduction of 0.28 (95% CI: 0.12, 0.71; $P = 0.05$) (8).

Because of studies such as these, in 1992, the US Department of Health and Human Services recommended the use of folic acid to reduce the number of cases of neural tube defects, estimating that 50% of neural tube birth defects could be prevented if women of childbearing age consumed 0.4 mg folic acid daily (9).

SECONDARY PREVENTION: OSTEOPOROSIS AND CARDIOVASCULAR DISEASE

Although effective primary prevention strategies are optimal for promoting human health, secondary prevention, or risk reduction, is also important. However, it is complex, particularly when it involves chronic degenerative diseases that are caused by multiple factors. Taking those at risk and reducing that risk to delay or avoid disease onset for as long as possible becomes the focus. The life cycle approach to disease prevention acknowledges not only the importance of genetics and environmental influences, but also the effects of time in the development of chronic degenerative diseases (**Figure 1**). In developing countries today, even poor children are displaying chronic degenerative disease risk factors such as obesity (10, 11) in addition to deficiency diseases. Even some diseases previously considered adult-onset, such as type 2 diabetes and hypertension, are also evident (12, 13). Starting life in a suboptimal unhealthy environment that does not support growth, be it an environment caused by poor diet or some factor in the built, social, or natural environment, may also increase the risk of future chronic degenerative disease development. Osteoporosis and cardiovascular disease (CVD) are 2 examples of diseases that exhibit cobwebs of risk factors that must be prevented and controlled starting early in life.

Osteoporosis

As defined by the World Health Organization, osteoporosis is the gradual decline in bone mass with age, which leads to increased bone fragility and fractures (14). Osteoporosis is estimated to affect 10 million Americans and will affect 14 million by 2020 (15).

Peak bone mass is fully established by 30 y of age, but most of the increase in bone mass is achieved in adolescence during the growth spurt (16). Age affects mean calcium retention, with maximal retention occurring in early puberty followed by a marked decline in late puberty (17). Failure to achieve optimal bone mass at the end of adolescence leaves an individual with less reserve to withstand normal losses in bone density that occur during later life (15). Risk factors for a low peak bone mass, and therefore an increased risk of osteoporosis, include low body mass index, low levels of weight-bearing physical activity, poor nutritional status due to low calcium and vitamin D intake, smoking, and genetic factors (15).

Regarding nutritional status, there is currently a downward trend in calcium consumption. A 1994 US Department of Agriculture survey found that in women, the average daily calcium intake fell below the Recommended Daily Allowance from the age of 11 y onward (**Figure 2**) (18). Dietary intervention in childhood is critical to increase peak bone mass and calcium reserves that can help to limit the rate of bone loss in later years (15). Otherwise, poor nutrition in early life will increase risks of future bone fragility and fractures occurring spontaneously or due to trivial injuries.

Cardiovascular disease

Cardiovascular disease risk factors, such as obesity, type 2 diabetes, hypertension, and hyperlipidemia, have been reported even in children and adolescents (10–13, 19, 20). These risk factors include excessive intake of food energy, dietary saturated and other fats, and cholesterol coupled with physical inactivity (21, 22). Compounding the situation is a "time bomb": the development of childhood obesity earlier in life is increasingly predictive of future obesity in adulthood (23, 24). The increased prevalence of these disorders in youth and young adults increases risks of premature morbidity and mortality and increased health care costs.

Diet and exercise interventions can have a beneficial effect on body weight, body mass index, serum cholesterol, and fitness in children (25–31), as shown in the Child and Adolescent Trial for Cardiovascular Health (CATCH) Project, the largest school-based program to examine CVD prevention and risk reduction strategies in children (32). CATCH examined 5106 schoolchildren (grades 3 through 5; ages 8–11 y) for 3 y to determine the effects of dietary and exercise interventions on CVD risk factors. In the intervention group, a decrease in the proportion of daily calories coming from saturated fats, although not reaching study goals, was achieved relative to a control group and was also sustained at follow-up 3 y later (32, 33). Similarly, self-reported vigorous daily activity was higher in the intervention than in the control group (32). However, although intervention children sustained higher levels of activity than did the control children, levels of activity steadily declined for both groups of children over the next 3 y (33). The intervention was not strong enough to prevent the encroachment of increasingly sedentary lifestyles.

It was better to prevent the problem altogether. In CATCH, maintenance of light weight (body mass index <15th percentile) was associated with the most favorable pattern of cardiovascular disease risk factors, and maintenance or achievement of light weight was associated with favorable changes in systolic blood pressure during early adolescence, despite the lower-than-expected prevalence of light weight (34). In contrast, normal-weight children who became overweight during the course of the study exhibited striking and adverse percentage changes in serum cholesterol (increased) and in both serum HDL-cholesterol (decreased) and apolipoprotein B concentrations (increased) (34).

Starting on the right path is critical to achieving a long life spent in good health. Clearly, identifying those at risk and implementing preventive measures via nutrition and other measures is required to shift the population to one with a reduced disease risk status. Trying to decrease excessive weight gain through nutrition and physical activity interventions will help those already overweight or obese and help prevent further weight gain (10, 11, 34).

STAYING ON THE RIGHT PATH

Once an individual starts on the right path to health, it is imperative to continue on it. This requires disseminating information and implementing interventions to the entire population to help all individuals continue to live healthy lives. However, it is not always clear what people should be told to maintain and improve their health. Interventions to do this can only be identified by examining the totality of evidence by constantly updating and summarizing relevant findings. An evidence-based approach allows evaluation of the data needed to choose the appropriate interventions and ultimately guide actions.

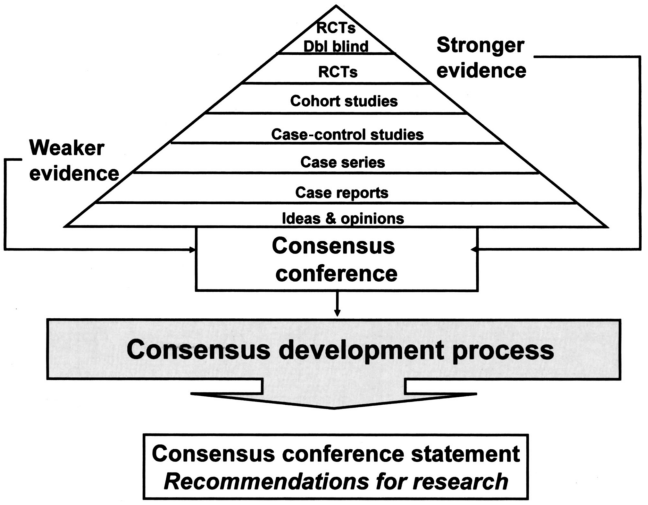

FIGURE 3. A paradigm to evaluate research to produce a consensus statement surrounding a particular topic. RCTs, randomized controlled trials; Dbl blind, double blind. Source: National Institutes of Health.

EVIDENCE-BASED APPROACHES TO SUPPORT EFFECTIVE NUTRITION ACTION

Most National Institutes of Health (NIH) recommendations are population-based, and especially rigorous assessment of the scientific evidence is needed for such population-wide recommendations. But what is the best paradigm for evaluating this evidence to determine the best course of action? One process used by the NIH to evaluate current evidence for making recommendations that affect many people in important ways is described in **Figure 3**. The pyramid represents the body of evidence, where the large base houses weaker evidence but denotes the abundance of it. As we climb up through each level of the pyramid, the quality of evidence improves but the quantity of studies available is inevitably reduced, because they are time-consuming and expensive to accomplish. The NIH has developed a process whereby all information in the evidence pyramid is considered and weighed to help develop a consensus judgment on its strength through an unbiased review process. The consensus statement produced summarizes what is known and also addresses needs for future research. New data feed back into the evidence pyramid until the data are conclusive enough to permit population recommendations to be made.

A life cycle perspective, together with an evidence-based approach to the decision-making process of choosing effective interventions that are well supported by evidence, is required to start on the path, stay on the path, and optimize the potential for healthier old age through effective intervention measures. An especially strong evidence base for prevention and treatment decision-making in nutritional intervention is needed if national programming is the objective. Although a theoretical rationale exists for nutritional intervention throughout the life cycle for all

those at risk of or already living with chronic degenerative diseases, evidence for each possible measure is required to support population-wide nutritional recommendations. Continuous evaluation and updating of the evidence is also required to continue down the correct path as more data accumulate.

When evaluating the evidence supporting a link between current nutrition, past nutrition, and disease in later life, the totality of the evidence must be carefully considered, even when the application is an intervention already in common use. Support for such caution about assuming that widespread practices are effective comes from the Women's Health Initiative. This included a hormone replacement therapy (HRT) trial. This popular and commonly used therapy among postmenopausal women failed to prevent heart disease. In 2002, the NIH stopped the estrogen plus progesterone trial because of increased risks of venous thrombosis and CVD (35, 36). In 2004, the estrogen-alone trial was stopped because of negative effects on cognitive function and dementia, increased risk of stroke, and lack of effect on coronary artery disease incidence (37, 38). Evaluating the evidence about HRT from this study has led to action and changes in prescribing patterns as well as in women's acceptance of these therapies.

Several initiatives aimed at developing evidence-based prevention and treatment strategies for nutrition interventions in aging Americans have been undertaken lately with good result. The American Academy of Family Physicians, the American Dietetic Association, and other professional nutrition, health, and social welfare societies conjointly launched the Nutrition Screening Initiative in the early 1990s (39), which institutionalized the concepts of nutrition screening and intervention in the health care of older Americans and specifically addressed 8 chronic degenerative diseases (40). Nutrition screening and interventions, when they are coupled with other effective therapies, are cost-effective and result in fewer complications, faster recovery, shorter hospital stays, and reduced hospital expenditures.

The Institute of Medicine at the National Academy of Sciences, and Health Canada developed the new Dietary Reference Intakes (DRIs) with funding from the NIH and other groups (41, 42). The DRIs now include specific nutrient standards for individuals aged >70 y, because it is clear that nutrient requirements change in aging adults as the result of physiologic, functional, and lifestyle changes.

The NIH has also examined several commonly used interventions of unproven or unquantified benefit and evaluated them for their relative utility. In recent years, these reviews have included n−3 fatty acid use in osteoporosis (43) and CVD (44). A study of routine use of vitamin and dietary supplements for chronic disease prevention is also now in progress. The arm of the Women's Health Initiative that is evaluating the potential of calcium supplements to reduce the risk of osteoporosis in postmenopausal women will soon be completed (45).

LINKING EVIDENCE TO ACTION: ADVOCACY

Ideally, evidence gives rise to advocacy on the part of those who desire to obtain or provide some service, and this gives rise to action. In real life, however, the process is more convoluted and recursive, with evidence and advocacy influencing action or treatment at many parts of the process. The Nutrition Screening Initiative actually stimulated a good deal of research on which later advocacy could be based, for example.

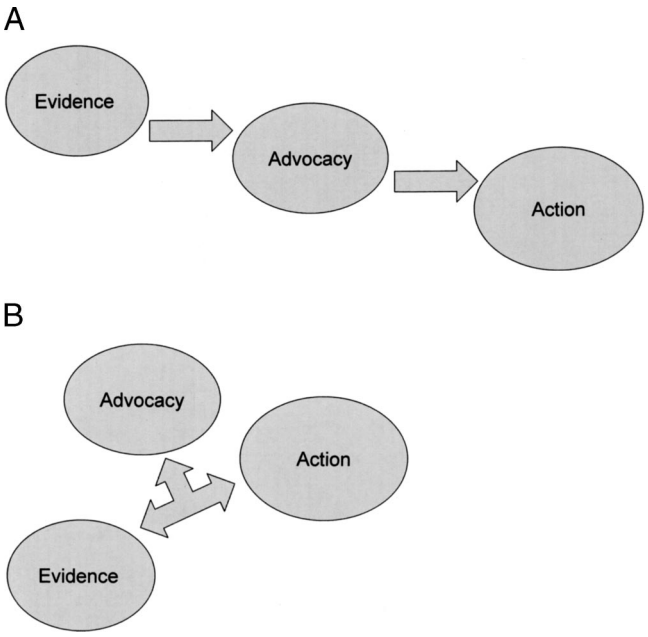

FIGURE 4. A: The ideal scenario for the development of the treatment process involves using evidence to give rise to advocacy, which in turn leads to action. B: The real-life scenario is more convoluted, with evidence, advocacy, and action interacting throughout the process.

Research is needed to generate evidence, and advocacy is required to generate research. Once the evidence is produced and validated, advocacy is again needed to move the argument for the intervention or treatment forward through public policy and decision-making. However, advocacy can be difficult to mobilize to summarize and promote research. Finally, policymakers need to review the evidence before making decisions and action occurs. This complexity is shown in **Figure 4**. Therefore, the path from evidence to action is neither linear nor always totally logical. Nor do the programs that do the most good necessarily get the credit or the budgets they deserve. For example, in the 20th century, public health advances delivered most of the 30 additional life-years we now have, but for the past several decades, most of the public health budget has gone to the discovery of new and costly therapies (3). Given the potential for a prevention-oriented, life cycle approach to reduce disease risk across populations, delay or prevent chronic disease onset, and reduce the morbidity associated with such disease, budgets may need readjusting to accommodate more such public health initiatives.

CONCLUSION

High-risk and especially population-wide approaches are both important to decrease mortality and morbidity and extend healthy living into old age. We cannot rid humanity of disease, but perhaps we can somewhat modify its impact. The goal of delaying disability in an increasingly longer life is valid, but the age of onset of chronic disease must be similarly delayed, or we will only achieve extended misery in those extra years. There is questionable merit, both for the individual and for society as a whole, in adding life to years if those incremental years are spent in poor health and misery.

A prevention-oriented, life cycle approach reduces the population's disease risk status with primary prevention strategies, such as proper nutrition. It can result in delayed disease progression and ultimately reduced disease incidence. Secondary and tertiary prevention involving a combined high-risk and population approach identifies those at high risk and protects or treats them, keeping as many as possible at low risk, and continues to shift the entire population to lower risk.

The social implications of more people living longer revolve around quality of life, health status, and resource requirements of an increasingly aged population. With a focus on and adequate resources available to implement prevention-oriented, life cycle approaches that successfully reduce risk, delay chronic disease onset, and mitigate nutrition-related morbidity in disease, it should be possible to achieve the desired outcomes. To bring this about, we must think about nutrition and other preventive measures early and often. The ultimate objective is to achieve more years of life with minimal years of compromised health. We do this by starting on the right path, staying on the right path, and dying young as old as possible. This is the best way to live to 100.

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