

CAN DIET PROLONG LIFESPAN?

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In the last fifty years significant increase in life expectancy has been found for older individuals. A solution to this problem may be found in nutrition as evidence by studies with animals, insurance company statistics, and folk wisdom. Many of the theories regarding the cause of aging are consistent with the observation of a beneficial effect from proper diet. The most life-prolonging diet is one which is low enough in calories so that no excess fat will accumulate on the body.

DIET AND AGING

Introduction

In the last half-century an increase in life expectancy at birth of about twenty years has appeared. During the same period, the life expectancy of a sixty-five year old has risen by less than one year.¹ Life expectancy at birth has increased due to control of the infectious diseases while life expectancy for the elderly has remained much the same since the degenerative diseases and the processes of aging are still largely beyond the control of medical science.¹⁻⁵

Restricting the quantity of food ingested will prolong the lifespan. This has been proposed as the most practical approach to increasing longevity in man.⁵ Modern research has scientifically confirmed age-old folk wisdom. In 3800 BC, the following inscription was made in an Egyptian pyramid: "Man lives on $\frac{1}{4}$ of what he eats. On the other $\frac{3}{4}$ lives his doctor." Temperance in eating and drinking in order to prolong life was discussed in the early Chinese writings of Huang Ti.⁶ From the Bible comes this statement: "Many have died of gluttony, but he who is careful to avoid it prolongs his life." (Ecclesiasticus 37:31) Shakespeare wrote: "Leave gormandizing; know, the grave doth gape for thee thrice wider than for other men." (King Henry IV, Part II, Act V, Scene V)

This review will discuss the experiments and statistics which show the effect of dietary restriction on lifespan, and will examine the explanations for this effect. Also, the relevance of animal studies to man will be argued and practical dietary recommendations will be given.

Dietary Restriction and Lifespan Prolongation

Osborne, Mendel, and Ferry⁷ are credited by various reviewers^{8,9} as being the first to show that diet

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restriction in animals could prolong lifespan. The first large-scale studies, however, were done by McCay many years later.¹⁰⁻¹⁶ In these experiments, one group of animals was fed an adequate diet in restricted amounts, and the lifespan of this group was compared to that of a control group which was allowed to consume all of the diet they desired (*ad libitum*). The lifespan of the restricted animals was prolonged by 50% due to decreased frequency of chronic diseases.¹⁷

McCay's work has been confirmed many times in all forms of life from protozoa to fish to rodents; the work of dozens of researchers has been thoroughly reviewed many times.^{5,8,9,18-23} In most cases, the cause of lifespan prolongation has been decreased incidence and severity of degenerative diseases.

Some of these experiments have been criticized since the degree of food restriction was so severe that immaturity and retarded growth resulted; if this were always the case it would render the 'McCay' effect unacceptable for man. However, employment of lesser degrees of food restriction in other experiments²⁴⁻²⁶ has resulted in lifespan prolongation without such negative side-effects; in fact, all that was necessary was to maintain the body free of excess fat in these experimental animals.

It has been stated that dietary restriction must begin in infancy for the effect on lifespan to be pronounced and that, in man, "the likelihood of this occurring is almost nil."⁴ This statement is partly based on the fact that most of McCay's experiments were done on young rats. Although it is true that the effect of restriction is greatest if started in early life,^{5,17,27,28} many experiments have shown that significant lifespan prolongation may result even if dietary restriction is not imposed until adult life.^{13,17,18,29-33}

Effect of Overweight on Disease and Longevity in Man

One may begin to consider the relevance of the animal studies to man with an examination of the effect of overweight in human beings. A multitude of insurance company statistics document an increased risk of the following diseases in overweight subjects: cardiovascular diseases, diabetes, renal diseases, liver and biliary tract pathology, appendicitis, problems in pregnancy and childbirth, hernia, degenerative joint disease and respiratory tract diseases, all resulting in decreased longevity.³⁴⁻³⁹ Some studies have found an increased risk of cancer with overweight.^{40,135} Studies show that the ideal weight is slightly below average;^{34,39,40} that even slight overweight confers added risks; and that risk is greatly decreased with loss of excess weight.^{37-39,41} The causes of increased risk associated with overweight and obesity have been examined.^{1,8,42-47} It is clear, therefore, that overweight in both animals and human beings facilitates development of pathology and shortens lifespan; "the longer the belt line, the shorter the life line."³⁹

Causes of Aging

The observations made on all forms of life that overfeeding shortens lifespan have led to the formation of the most accepted concepts regarding the causes of aging. They are:

1. Crosslinkage theory: many authors have noted that biological aging in connective tissue is analogous to the process that occurs when leather is tanned—increased numbers of crosslinkages develop between molecules of collagen, the subunit of connective tissue. This results in loss of elasticity, reduced swelling capacity, increased resistance to enzymes, and a tendency toward embrittlement; physical manifestations would include wrinkling of the skin and stiffness of joints.⁴⁸⁻⁵⁰ Mechanical and chemical measurements of the age of collagen show that crosslinkage, and therefore biological aging, can be retarded in rodents by restriction in food intake.⁴⁹⁻⁵² This dietary effect has been explained: "With a low caloric diet, oxidation proceeds rapidly to the innocuous end-products, carbon dioxide and water. On overeating, intermediate products accumulate at the metabolic 'bottlenecks,' and many of these are crosslinking agents.⁴⁸ These agents accelerate aging in collagen; change immunological behavior of proteins which may be a factor in autoimmune diseases; and possibly may contribute to atherosclerosis by further changes in proteins and destruction of elasticity in arterial walls.⁴⁸ Support for this theory is found in the discovery that certain intermediate metabolites are potent crosslinkage agents.^{48,53}

2. Hypothalamic-pituitary-thyroid theory: this theory explains aging as a normal process that may be accelerated by increased thyroid gland activity. Such excess activity may result from excess food intake, and may result in excess metabolic activity causing excess organ work: "as the work output of an organ rises, it ages more rapidly and prematurely develops age-related pathology which leads to organ failure."⁸ Dietary restriction resulting in lifespan prolongation is known to be accompanied by decreased pituitary, thyroid, and gonadal endocrine activity,⁵⁴⁻⁶⁰ and this provides support for this theory.

3. Growth rate theory: this theory states that "rapid growth rates, structural or biochemical, are not commensurate with prolonged lifespan."⁶¹ Dietary restriction in animals slows the growth rate as it prolongs life.^{17,20,61-67} Dietary excesses leading to obesity in man will accelerate skeletal maturation, onset of puberty and menarche.⁶⁸⁻⁶⁹ The finding that growth rate is inversely related to longevity has led to the conclusion that "excessive nutrition may well contribute substantially to the incidence of pre-senile diseases in prosperous people today, and hence to an effective acceleration of statistical aging."²⁰ (See also references 63,70-72). The age of onset of puberty has been steadily decreasing in the last century, and some primitive populations reach maximum size years later than is found in more advanced populations; this

is thought to be a result of differences in nutrition.¹ Indeed, it would seem that the nutritionist's old tenet "the bigger the better" is false.¹⁸

4. Immunological theory: many researchers believe that a breakdown in normal immune functioning "underlies the deteriorative processes associated with aging."⁷³ A mild degree of dietary restriction will, however, cause slower maturation of the immune system and thus keep this system younger longer, resulting in prolonged lifespan.^{67,74-83} Experiments show that a strain of rodents which is highly susceptible to early onset of fatal autoimmune disease will live considerably longer on a restricted food intake as compared to controls fed *ad libitum*. This theory has been thoroughly reviewed.^{73,84}

5. Genetic code error theory: proponents of this theory propose that "dietary restriction reduces the use of the genetic code and thereby minimizes genetic imperfections as they occur in later life."¹⁹ Enzymes are proteins synthesized by the cell with the participation of its genetic apparatus. Some studies have shown that there are age-related changes in patterns of enzyme activity in a specific tissue and, therefore, it has been proposed that such changes may reflect biochemical and biological aging. Diet restriction will often retard age-related changes in enzyme activity concurrent with lifespan prolongation. This theory has been thoroughly reviewed.^{5,19,22,23,61,85-88}

6. Free radical theory: free radicals are highly reactive, chemically unstable substances which may cause many of the degenerative changes associated with disease and aging.^{89,90} The mechanism of action is thought to be damage (more-or-less induced rancidity) to the polyunsaturated lipid components of cellular membranes.⁹¹ Free radical reactions may be terminated by antioxidants (such as vitamin E) and some studies have shown that adding antioxidants to the diet of experimental animals will prolong lifespan,^{89,92-94} at least partly due to inhibition of cancer development.^{95,96} The free radical-aging-antioxidant connection has led to the widespread recommendation that vitamin E be added in supplement form to the diet. However, benefit from dietary antioxidant usage is not supported by concrete evidence,⁹⁷ has not been independently substantiated,³ and may in fact be efficacious for reasons having little to do with the free radical theory.⁹⁶ For instance, many of the animals in whom lifespan has been prolonged by administration of antioxidants have low body weights; therefore, the explanation may be appetite depression resulting in dietary restriction, not free radical reaction inhibition.¹⁹

7. Law of entropy: this law states that there is a "natural tendency of systems to become increasingly disordered with time."⁹⁸ In the body this may be accelerated by excess food intake: "as we eat more, we increase our total energy content and more disorder occurs."⁹⁸ The prescription for increased longevity based on this law would be to keep food intake to a

minimum, "just enough to satisfy body needs . . ."⁹⁸

8. Inadequate diet theory: lifespan may be shortened by use of an inadequate diet. Such a diet, though seemingly adequate due to its ability to support 'normal' health and growth and longevity for many generations, may not provide for as long a lifespan as would an improved diet. Sherman fed a diet to a group of rats which was able to support normal function for over forty generations but which was inferior in regard to lifespan when compared to an improved diet.⁹⁹⁻¹⁰²

9. Accumulation of cellular breakdown products: such substances "might be deleterious to the cell if they accumulated sufficiently."¹⁰³ The mechanism of action may be increased crosslinkage in connective tissue, or increased number of free radical reactions.

Relevance of Animal Studies to Man

It is obvious that "the purpose of research on aging is to enlarge our understanding of biological processes in a way that will ultimately be of value to human beings."¹⁰⁴ Many researchers have indicated that work with animals is relevant to man; one states that, in experiments on diet restriction and longevity, "the similarity of results in all organisms belonging to different groups, phylogenetically so far separated, leads to the conclusion that the amount of food ingested might be a basic biological factor affecting the lifespan of all living organisms including man."¹⁰⁵ Making generalizations between species may have validity since "biochemically the cells of a whale are very similar to those of an amoeba, in as much as both have nuclei and cytoplasm, and comparable metabolisms of energy and nitrogen."¹⁰⁶ The fact that "the diseases leading to death in man affect the same tissues of those in the rat (kidneys, arteries, and heart), though the lesions differ in nature,"²⁶ lends further support to generalizations. Another researcher noted that "nutrition offers a promising approach to the problem" of prolongation of lifespan¹⁷ and "there is no evident reason" why modifications of diet would not decrease the incidence of certain diseases of aging and prolong the lifespan in man as it has in animals."¹⁰⁷ Other scientists have made similar statements in regard to autoimmune diseases⁸² and many other diseases of aging.⁷⁸ One researcher has even recommended dietary trials in man.²³

Some researchers state that it would be unsafe to restrict the diet in man since there might be an increased risk of infections, impairment of general physical development or specific physiological systems, and increased risk of malignancies later in life:^{18,21} also, there is fear of retardation of skeletal¹⁰⁸ or mental¹⁰⁹ development. However, since it is known that dietary restriction of a degree that will result in the body being free of excess fat will prolong life in animals, and since there is no documented instance of physiological dysfunction from such a mild degree of restriction, it does not seem reasonable

to oppose such a dietary recommendation. In support of this are insurance company statistics which show that slight underweight is associated with the least risk of degenerative disease, and therefore the longest lifespan.

It is pertinent to ask if anyone would voluntarily restrict his diet in order to prolong life. At least one author believes that people would prefer to satisfy their food desires rather than live a long life.⁵ But regardless of what percentage of people would prefer to "eat to live" rather than "live to eat," the least that any responsible physician should do is present such an option to those who come for advice and treatment. And, following a convincing presentation, the physician may be surprised at the number of patients who would be willing to change.

Dietary Recommendations

Life should begin with prolonged breast-feeding. Besides its many well-known advantages,^{110,111} such a diet provides for slower growth when compared to other types of feeding, and this is correlated with increased longevity as already mentioned.¹¹²⁻¹¹⁴ Also, breast-feeding in infancy, and food consumption in childhood which is designed to maintain the body relatively free of excess fat, may protect against overweight later in life; this has been explained in terms of the still unproved adipocyte-proliferation hypothesis.^{44,115} But, regardless of the validity of this hypothesis, it would be wise to avoid overeating in early life if only because this would develop a habit which may be hard to break later on.

After puberty, the amount of food should be restricted to the point where no excess fat would accumulate. This, among other changes, would require a reevaluation of Western esthetic standards: a relatively fat-free body today is usually associated with illness, probably because in most cases in Western societies this is the only time such a physical state is achieved. It would be necessary to change this, however, if lifespan were to be prolonged on a large-scale basis.

In order to achieve the necessary caloric restriction, the amount of fat in the diet should be greatly curtailed since, gram for gram, fat provides 2½ times more calories than either protein or carbohydrate.¹¹⁶ Currently, the average American diet is 40% fat; a US government report recommends that this be decreased to 30%.¹¹⁷ However, even this amount of fat greatly exceeds the physiological requirements for the foodstuff;¹¹⁶ therefore it is recommended that fat be limited to less than 10% of the diet. Foods high in fat are oils, lard, hydrogenated shortening, butter, margarine, bacon, salad dressings, meats, poultry, fish, dairy products, and eggs; foods low in fat are fruits, vegetables, legumes, cereals, and flours.¹¹⁸ It would be wise to greatly decrease the use of the foods high in fat, not only for caloric-restriction reasons, but also because fat has been shown to have a specific life-shortening effect in animals.^{119,136}

Protein should be consumed in quantities sufficient to meet the needs of the body only, especially since excess protein is thought by some to be the most important single aging-accelerator.²³ In any case, there is no physiological justification for consumption of 3-4 times more protein than the body needs and this is certainly the case in the US.¹¹⁶⁻¹²⁰

Carbohydrates should be used in amounts necessary to meet the caloric need. But, in a calorie restricted diet, in order to provide enough vitamins and minerals, only unrefined carbohydrates with their micronutrients still present should be used. Refined sugars and flours should be avoided even if enriched, since only a small percentage of the essential nutrients removed in processing are replaced in the enrichment process. The best carbohydrate-containing foods are the fruits and vegetables since, in comparison to the cereals and flours they contain far fewer calories. For instance, one pound of whole wheat flour contains 1510 calories, one pound of celery 58 calories, one pound of apples 242 calories.¹²¹

Although studies have shown that intake of vitamins in excess of the recommended daily allowance is correlated with increased lifespan,¹⁹ there is no need to use supplements if the diet described above is used. Intake of 1½ carrots and 2 oranges per day would provide three times the recommended daily allowance of vitamin C and 1.7 times that of Vitamin A.¹¹⁸ Also, since the evidence regarding the effect of antioxidants on lifespan is weak, and since the recommended diet would be rich in vitamin E (dark green leafy vegetables, nuts, and legumes are rich in 'E'¹¹⁸), and low in polyunsaturated fatty acids which increase the need for 'E', there is no need for supplementary 'E'. The case with minerals is analogous to that with vitamins.¹²⁴

The final dietary consideration is total caloric intake. The recommended daily allowances for calories should be regarded sceptically since, using this standard as a reference, about 70% of the world's population is undernourished.¹²⁵ It is indeed possible, if not probable, that "the 30% of the world's population who have an 'adequate' intake are really eating too much" and that "the energy requirements of man and his balance of intake and expenditure are not known."¹²⁵ Other lines of reasoning support this argument.^{126,127} Therefore, it is recommended that caloric intake should strike a balance between hunger satisfaction and maintenance of slight underweight.

Physicians could further well-advise their patients by recommending a program of daily strenuous exercise which not only would help keep the body weight at a minimum, but also may have an anti-aging effect.^{73,98,128-134}

Conclusion

Throughout history, dietary restriction has been recommended as a means by which lifespan may be prolonged. In the twentieth century, such folk wis-

dom has been confirmed both in the laboratory and by use of insurance company statistics. Many theories as to the cause of aging have been formulated on the basis of the inverse relationship between caloric intake and longevity and these theories have been briefly reviewed. All those involved in nutritional guidance might greatly benefit their clients by recommending a diet designed to allow for prolonged lifespan. Such a diet contains enough calories to fulfill the physiological need, but not allow excess fat accumulation; it is low in fat and protein, and high in complex carbohydrates; and it does not need to be supplemented with vitamins and minerals since it easily fulfills the need for these micronutrients. □

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