Does a Reduced Fat Diet Cause Retardation in Child Growth?1

ROBERT M. KAPLAN, PH.D.,*2 AND MICHELLE T. TOSHIMA, PH.D.†

*Division of Health Care Sciences, Department of Community and Family Medicine, 0622, University of California at San Diego, La Jolla, California 92030-0622; and †Department of Rehabilitation Medicine, University of Washington, Seattle, Washington 98195

Background. A diet low in saturated fat and cholesterol is strongly recommended by the American Heart Association and the National Cholesterol Education Program as a way to prevent coronary heart disease. In addition, the National Cancer Institute has suggested that dietary fat restriction may also prevent the development of some cancers. However, the American Academy of Pediatrics reviewed the same evidence in relation to children and concluded that the major dietary changes recommended for adults should not be prescribed for children.

Methods. In this article, we review the evidence for the detrimental consequences associated with dietary fat restriction for children. Evidence from studies on secular trends, migration, and vegetarian communities suggests minor effects of dietary fat restriction upon growth. In addition, there is some evidence indicating that children who are placed on severe dietary restriction during growth periods may experience growth stunting. Virtually all of the published studies have serious methodological limitations.

Conclusion. We conclude that dietary fat restriction may have some small, but measurable, effects upon growth. © 1992 Academic Press, Inc.

INTRODUCTION

Coronary heart disease (CHD) remains the leading cause of death in the United States (1). The American Heart Association suggests that clinical, laboratory, and epidemiologic studies consistently identify specific lifestyle factors in persons at risk for heart disease (2). These risk factors include a diet high in saturated fat and cholesterol. Cholesterol is the most abundant lipid found in lesions associated with CHD. Serum cholesterol (TC) levels have been identified in a variety of epidemiologic studies as correlates of CHD mortality (2). As a result of this evidence, the American Heart Association has recommended large scale dietary modifications in an effort to reduce CHD. These include a reduction in total fat and a reduction in dietary cholesterol (3). In a related statement, the American Heart Association recommended a prudent diet for children. The statement suggests that adult lesions begin early in life and may be the result of early dietary habits. The Association recommended a prudent diet for children with reduced fat content (4).

In addition to the American Heart Association, other groups, including the American Health Foundation (5), the National Institutes of Health Consensus Development Panel (6), and most recently the National Cholesterol Education Program (7), have also recommended restrictive diets for children. Upon review,
the committee on nutrition of the American Academy of Pediatrics (8) questioned these recommendations. They noted that fatty streaks can be found in the aortas of virtually all children by the age of 10, quite independent of their diet or their health behaviors (9). The Academy expressed serious reservations about accepting the contention that these fatty deposits in the vessels of children justify major dietary change in childhood. In addition, they noted that studies have failed to identify a correlation between diet and cardiovascular risk factors in U.S. children (10).

The American Academy of Pediatrics group also questioned the value of greatly reducing total fat in the diet. The committee alluded to some studies in which fat restriction may be associated with reductions in linear growth. Their conclusion was that optimal total fat intake for children is not known. However, they suggested that 30–40% of calories as fat are adequate for growth and development. The American Heart Association (4) set 30% as the upper limit for children over the age of two, as did the National Cholesterol Education Program (7).

Some recent papers have raised serious questions about the impact of dietary fat restriction upon growth in children. For example, Pugliese and colleagues (11) suggest that “parental misconceptions and health beliefs” about an appropriate diet for infants can cause failure to thrive. In this review, we investigate the evidence that restriction of dietary fats causes growth deviations in children. Evidence for these contentions comes from studies on secular trends, migration, childhood illnesses, vegetarian populations, and weight loss. We will consider each of these areas separately.

SECULAR TRENDS IN GROWTH

Some evidence for the effects of fat restriction comes from secular trend studies of various population groups. For example, the city of Sendai in Japan has measured the heights and weights of children every spring and autumn since 1936. These measurements were taken even during the hardships of the second world war. The secular trends in height and weight of the Japanese children dropped during the war. Following the war, a steady rise in height and weight was noted to have occurred each year through the late 1970s (12). The increases in growth correspond to increases in the consumption of fats and proteins in the Japanese diet. Recent evidence suggests that there has been a gradual increase in body fat in the Japanese population with a corresponding systematic increase in TC and low-density lipoprotein cholesterol (LDL-C). These data suggest that the adoption of a more Westernized diet in Japan increases risk factors for CHD, as well as increases the median height and weight of the children. Interestingly, although height and weight have increased, the systematic increases in blood TC in Japan have not been greeted by a corresponding increase in cardiovascular disease (13). The decline in height among Japanese children during the second world war is of some interest. This dip in the secular trend toward increased stature has been attributed to the restriction in nutrition during the war years. Similar dips in the secular trend toward increased stature have occurred in other countries. For example, Brundtland and colleagues (14) reported on mean heights of schoolchildren in Oslo, Norway, between 1920 and 1975. For children of a variety of ages,
there has been a strong secular trend toward increased height with a distinct reversal in the World War II years. This reversal has been attributed by some to a decrease in the availability of meat and dairy products. However, the evidence does not clearly allow a separation of the effects of these components of the diet from the effects of total calories and protein.

Longer term secular trends in Belgium have been reported by Susanne (15). Earlier reviews by Tanner (16) and Van Wieringen (17) demonstrated that children in the current generation are taller than those in the 1940s, who were in turn taller than children at the end of the 19th century. Susanne put together data from a variety of different studies to compare the average height of children ages 3 to 21 years estimated from the years 1835, 1929, 1948, 1960, and 1977. There has been a systematic evolution of height in Belgium with children at each age level systematically taller at successively more recent evaluations. The rate of change appears to be greater in more recent studies. Considering adult height, the trend was about 0.4 cm per decade between 1845 and 1930, 1.2 cm per decade between 1930 and 1950, and 2.0 cm per decade after 1950. Similar data have been reported for The Netherlands (17), Italy, and other countries (18).

Susanne attributed some of the changes in height to changes in the Belgian diet. The most rapid increase in height has been since 1950. A review of available data on changes in the consumption of specific foods between 1955 and 1978 suggested a substantial increase in the consumption of meat and cheese and a slight decrease in the consumption of cereals and potatoes during this period. Among the meats consumed, the greatest increase was in mixed or minced meats that have higher fat contents. Thus, the most rapid increases in height corresponded to increased consumption of high fat foods. In secular trend studies, the nearly universal increase in height and weight across generations has been attributed to a number of factors, including better nutrition, better health, and better living standards. Although genetic factors impact growth and development, environmental factors also play a part. Historically, as countries became industrialized, strong temporal correlations between improved living conditions and positive secular trends were noted. In England for example, there were substantial differences in height between city dwellers and those who committed their lives to rural agriculture. Those in cities were more likely to eat higher fat diets while those in rural areas in the 17th and 18th centuries survived on a monotonous diet of bread, potatoes, root vegetables, and tea. Salt pork and bacon was consumed less than once per week and fresh meat was almost never consumed (19). As with any cross-sectional data set, however, there are limitations in the level of sampling and methods of measurement.

Anthropological studies suggest that human-like species have varied considerably in their meat consumption. Stone tools used in hunting were manufactured by *homo habilus* about 2 million years ago. *Homo erectus* consumed meat in substantial amounts about 1.8–1.6 million years ago (20). It is estimated that *homo erectus* and some early *homo sapiens* derived about half of their calories from plant sources. However, those in other areas were successful hunters and may have consumed about 50% of their calories as meat (21). Over the course of time, the amount of meat in the diet was reduced and eventually became replaced with
vegetable sources. According to Eaton and Konner (22), "This shift had predomina
ant morphological consequences: early European *homo sapiens* who enjoyed an
abundance of animal protein 30,000 years ago were an average of six inches taller
than their descendants who lived after the development of farming" (p. 284). 
Other evidence from relatively more recent history supports similar conclusions. 
The Paleo-Indians who lived about 10,000 years ago were big game hunters. Fossil
records suggest that they were considerably taller than their descendants, who ate
little meat and derived most of their nutrients from vegetable sources (23).

**MIGRATION STUDIES**

Numerous studies conducted on various ethnic population groups have consist-
tently shown that migration, particularly from rural, developing countries to in-
dustrialized nations, is often accompanied by changes in anthropometric charac-
teristics (24–29). The evidence consistently shows that migrant populations are
larger in size than nonmigrant populations within the same ethnic group and that
children of immigrant parents tend to be bigger than children born to nonmigrant
parents of the same country. What is uncertain, however, are the factors respon-
sible for this trend. Evidence from several migration groups will be considered in
the following section.

In Israel, where recent immigrants make up nearly 50% of the population,
Tartakovsky *et al.* (29) found that in both men and women, native-born Israelis
are significantly taller (*P* < 0.01) than each of the immigrant groups. Data on
descendants of Mexican immigrants in Texas (30) indicated significantly higher
values in 13 of 20 morphological characteristics measured among the offspring of
the immigrant population. Height measurements showed that the migrant popu-
lations were significantly taller (*P* < 0.001) than nonmigrant populations (31).
Although the trend was in the same direction for parents, the difference in height
was not significant.

Similar findings have been reported for Asian groups. Japanese men living in
Honolulu and San Francisco are similar in height, and both groups are taller than
their counterparts in Japan. The same studies report increased dietary fat con-
sumption in San Francisco and Honolulu in comparison to Japan. Furthermore,
this difference was more pronounced among the younger age groups (25). Dewey
*et al.* (24) obtained anthropometric data on 526 healthy Southeast Asian children
(ages 2–6) during the period from 1980 to 1984 and compared them with growth
standards established by the National Center for Health Statistics (NCHS) (32).
The mean heights for the children were generally between the 5th and 25th per-
centiles according to NCHS standards. A disproportionate number of children
(39%) fell below the 5th percentile of height for age. Olness *et al.* (33) compiled
anthropometric measurements of 1,650 healthy Indo-Chinese refugee children
living in Lao, Cambodian, and Thai camps and villages, and compared them with
U.S. growth standards for children. Nearly 50% of the refugee children as a whole
were two standard deviations below the U.S. reference mean. About 20% of the
children fell two standard deviations below the Thai mean. These comparisons of
Asian and U.S. children must be interpreted cautiously since diet may be only one
factor in determining height differences. Certainly genetic predispositions must
also be considered. However, migration studies and intervention studies (see below) do suggest height differences even within genetically similar groups.

Table 1 summarizes the results of the migration studies. The differences in physical stature documented in the migration studies raises several important questions, including: (a) To what degree does nonrandom sampling or preselection of migrant individuals from among the migrant population affect the observed differences? (b) In what way are migrant individuals different from nonmigrant individuals, and what impact does this have on differences in height and weight status? (c) Is the basis for the noted difference in height, genetic or environmental or both? (d) To what degree does acculturation and assimilation of the migrant group to the predominant culture have an effect? and (e) What are the implications of such findings?

With the exception of the study by Livshits and Kobyliansky (31), the differences in physical stature between the various population groups studied were attributed to environmental influences and more specifically to diet. For example, in the study of Japanese in Japan, Honolulu, and San Francisco, dietary analyses revealed aspects of the Japanese diet that may have contributed to the differences in stature. Although the total caloric intake across all three groups was fairly equal, the Japanese in Japan consumed less fat and animal protein and more carbohydrates than the Japanese in the United States. Furthermore, the proportion of fat in the diet consumed in Honolulu is substantially greater than that eaten in Japan, and the proportion of fat eaten in California is greater yet. Thus, the authors concluded that the differences noted in height, especially among the younger age groups, may reflect nutritional differences.

The marked differences noted between the NCHS growth standards and the Indo-Chinese refugee children and Southeast Asian preschool children have also been ascribed to nutritional factors. These nutritional factors are determined by cultural, economic, and geographic backgrounds. Support for this explanation comes from studies in which children raised in upper-class and professional families from diverse ethnic backgrounds (Bangkok, Chang Mai, Egypt, Togo, Haiti) have significantly higher mean height and weight values for their age in compar-

<table>
<thead>
<tr>
<th>Study</th>
<th>Sample</th>
<th>Height changes (native born – immigrant) (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tartakovsky et al. (29)</td>
<td>Israeli-born males and females and immigrants to Israel (N = 1411 males and 961 females)</td>
<td>Male 3.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Female 2.1</td>
</tr>
<tr>
<td>Boas (73)</td>
<td>American-born male Jews and immigrant male Jews</td>
<td>3.5</td>
</tr>
<tr>
<td>Shapiro and Hulse (28)</td>
<td>Hawaiian-born Japanese and Japanese immigrants to Hawaii</td>
<td>4.0</td>
</tr>
<tr>
<td>Lasker (27)</td>
<td>American-born Chinese and Chinese immigrants to America</td>
<td>2.0</td>
</tr>
<tr>
<td>Kagan et al. (25)</td>
<td>2183 native-born men in Japan 8066 male immigrants to Hawaii 2296 male immigrants to California</td>
<td>1.52 1.74</td>
</tr>
</tbody>
</table>
parison to less fortunate children. In fact, the growth standards for these children from well-to-do families are comparable to U.S. standards. Thus, socioeconomic background has been noted to be positively correlated with growth status and is most likely the result of better nutrition and health care. Less privileged children from Third-World countries may have a growth potential that parallels U.S. growth standards.

Although migration studies are intriguing, migration is typically confounded with several other variables. For example, the stronger and healthier members of a group may be more likely to move. Migration is also confounded with other stimulation and environmental change that may be independent of diet. Thus, although the findings from migration studies are provocative, these factors need to be considered when evaluating the results.

EFFECTS OF VEGETARIAN DIET UPON GROWTH AND DEVELOPMENT

In recent years, there has been a growing interest in understanding the effects of vegetarianism on the health and nutritional status of children. The vast majority of children raised on vegetarian diets in the United States were raised in Seventh Day Adventist families or were members of immigrant families with well-established vegetarian dietary regimens. More recently, however, there has been a steady rise in vegetarianism among other subgroups of the U.S. population. In a survey of 100 recently converted vegetarians, 35% indicated becoming vegetarians for health reasons (34). Thus, next to religious/philosophical reasons, a disproportionately large number of "nouveau" vegetarians cite health benefits as the predominant reason for adopting a vegetarian diet. Most vegetarian adults receive adequate nutrition and are in good health (35-37). In contrast, far less is known about the suitability of a low-fat diet for young children. The focus of this section is to review the current literature on vegetarian and low-fat regimens in children and the impact of these diets on growth and development.

Definitions

Vegetarian diets are commonly divided into one of three categories. In all three categories, meat, fish, and poultry are not consumed. The lacto-ovo vegetarian diet, considered the most lenient of the three, allows for milk, dairy, and egg consumption. Lactovegetarians, on the other hand, consume milk and dairy products, but do not eat eggs. The total or pure vegetarian diet, often referred to as the vegan diet, contains no animal products. The Zen macrobiotic diet is the most extreme. Followers of this largely spiritual dietary regimen progress through 10 dietary stages. In the first stage, animal products are eliminated. Subsequent stages require the curtailment of more and more food items. By the last stage, only brown rice and water are consumed.

Potential Benefits

There are numerous studies documenting the benefits of a vegetarian or low-fat diet in adults, including lower blood pressure levels in the Seventh Day Adventist adults (38), lower serum TC levels (39), and lower mortality from both CHD and cancer (40-42). Recent studies have also reported lower rates of osteoporosis
among adult vegetarians in comparison to nonvegetarians (43). However, experts have not always promoted the health benefits of low-fat diets.

Animal experiments early in the 20th century supported the use of meat in order to promote growth. In a carefully controlled study reported in 1912, Slonaker divided 16 rats into two groups. Both groups were given a varied and abundant supply of vegetables, grains, nuts, and fruits. One group received only this vegetarian diet while the other group received the same diet with the addition of meat 2 to 3 times per week (omnivorous group). All other aspects of the animal environments and genetic background were systematically controlled. Upon follow-up, the growth of the vegetarian rats was significantly retarded. Further, the omnivorous rats were more active and completed 7.5 times more work (as measured by wheel-turn revolutions) during their lifetimes. Further, the omnivorous rats lived nearly twice as long as the vegetarian rats (44). Slonaker's animal findings reflected the zeitgeist of the early 1900s. Thompson's 1903 text on *Practical Dietetics* included the argument, "In regard to an exclusive or almost exclusive vegetable diet for man, the universal experience has been that while it may keep him in apparent health for some time, it eventually results in a loss of strength and general resisting power against disease, which becomes evident after some months, if not before. Animal food in some form must be regarded as absolutely essential for all races" (45). The influence of these early 20th century scholars may have paved the path toward promotion of a U.S. diet high in animal fat. Because of concern about chronic heart disease and cancer, the pendulum has now swung in the other direction with many contemporary authorities advocating a vegetarian, or at least a low-fat diet.

**ARE LOW-FAT DIETS GOOD FOR CHILDREN?**

Although the literature on adults suggests some health benefits of a low-fat diet, it does not provide adequate information on the potential benefits of such diets for children. A widely held belief is that the early phases of atherosclerotic lesions may begin in childhood (46). The belief is based on evidence from autopsies of young men killed during World War II, Korea, and Vietnam suggesting the initial stages of development of coronary artery lesions (47, 48). There is some controversy, however, concerning the progression of atherosclerotic lesions from childhood to adulthood. One recent study of 702 patients with familial hypercholesterolemia from Japan also raises questions about the age at which CHD begins. Of the patient sample, 10% of the men and 22% of the women had experienced a myocardial infarction. The rest of the sample was at risk and varied in age. From the entire sample, 110 male and 56 female patients underwent coronary angiographic evaluations to determine the degree of stenosis in the coronary artery. Regression methods were used to relate stenosis to age. The results suggested that the disease process (as detected by angiography) does not begin before age 17 for males and age 25 for females in those individuals from high-risk families (49). Thus, the findings suggest that any attempts to lower lipid levels will have little value before late adolescence. However, these studies do not rule out the possibility that fatty streaks, not detectable via angiography, may appear at earlier
ages. These streaks, that could result in plaques later in life, would be potentially preventable with early intervention.

_Potential Consequences_

Only a few studies have investigated the effects of low-fat diets for children. Most of these have concentrated on the impact of the diet and nutrition upon growth. The impact of vegetarian diets on various nutritional measures, such as iron, calcium, and riboflavin, is significant, especially for a growing child. Studies have examined the effects of a vegetarian diet on the nutritional status of children, the outcome variable being the percentage of RDA requirement for each nutrient.

Some vegetarian diets are low in energy content in comparison to the average U.S. diet. The low energy intake in vegetarian children has been cited for the following three reasons: (a) The staple foods in vegetarian diets have low energy density; (b) There is poor digestibility of many of the vegetarian foods that are high in energy density; and (c) The fat content of these foods is low. For example, to meet his/her energy requirements for a day, a small child, 1 to 3 years of age, would have to consume 6 cups, or approximately 2 lb of cooked rice, wheat, or beans (50).

_Depressed Growth_

Growth is a good indicator of a child’s general health and nutritional status. Unfortunately, few systematic studies have investigated the growth patterns of children raised on vegetarian or other low-fat diets. Following are citations to a few of these studies.

In 1982, Dwyer _et al._ reported the results from a preliminary investigation into the nutritional status of a group of 39 preschool children who followed either a macrobiotic diet or one of the other types of vegetarian diets. The children, as a group, were shorter in stature but not lighter in weight than National Center for Health Statistics (NCHS) standards. Approximately 80% of the children were under the 50th percentile for height. In all but six cases, the children were shorter than might be expected given the height of their parents. However, the relatively small number of children studied limits the conclusions that could be drawn.

Dwyer and colleagues (51) went on to study the growth patterns of a larger sample of 142 vegetarian and 229 nonvegetarian children, ages 3 weeks to 6 years old. The height and weight of the children were measured and then fitted to growth curves using Jenss and Bayley’s (52) regression equation. The growth curves for both height and weight of the vegetarians were equal to or lower than those for the normative population at all ages, independent of parental size and birth weight. The actual variation between the two groups did not exceed 2.0 cm in height or 1.0 kg in weight. In addition, the authors found that the most striking differences in height and weight between the vegetarian and normative group occurred when the children were 12 to 35 months old. This was the approximate time that most of the children were weaned off of breast milk and started on their respective diets. These results provide some evidence that a vegetarian diet in young children does affect growth patterns, though the observed decrement was slight.
Shull et al. (53) assessed the food intake and growth pattern of 72 vegetarian children under 5 years of age. The height and weight measurements were compared to the normative population in the Harvard Longitudinal Study of Growth and Development (54). Although vegetarian children under 2 years of age were below the normative growth rates, after 2 years of age, growth accelerated and approximated the normative sample.

Trahms and Feeney (55) addressed the issue of growth in vegetarian children from a slightly different perspective. They examined children who had changed from a pure vegetarian diet to a less restrictive type of vegetarian diet. Among the children they studied, there was a tremendous growth spurt over a 2-year period following change in diet. During this period, mean height increased from the 4th to the 41st percentile, and mean weight increased from the 15th to the 38th percentile. The striking changes were attributed to the animal protein intake allowed in the less restrictive vegetarian diet. However, there may have been other confounding factors and it is difficult to infer causation without a control group.

In Great Britain, Sanders and Purves (56) assessed the nutritional and growth status of 23 children on vegan diets. Energy intake, in all but two children, was below levels recommended by the Department of Health and Social Security (DHSS). Furthermore, although the anthropometric measurements of height and weight showed the children to be within normal ranges, for the most part, they were below the 50th percentile when compared with normative standards. This finding is similar to that from Dwyer and colleagues (51).

Sanders (57) more recently reported on the status of the same 23 vegan children, in addition to 16 new children. As reported previously, this longitudinal follow-up found intakes below those found in nonvegetarian children, and this difference was greatest in the 2- to 4-year-old age group. Although the energy intakes for the vegetarian children were below the UK recommended daily allowance, the growth of the vegan children was essentially normal. At most, there was a tendency, especially for the boys, to be slightly smaller in stature and lighter in weight than nonvegetarian children.

Similar investigations on vegetarian practices and the growth and development of children have been conducted in The Netherlands. Van Staveren and Dagnelie (58) reviewed four studies that addressed this issue. Based on the results of the investigations, they concluded that only children raised on macrobiotic diets, the most strict form of vegetariansim, are at risk for retarded growth. In addition, once growth is depressed, there does not appear to be a point at which the children catch up to the normative sample.

**COMMENTARY ON VEGETARIAN STUDIES**

There are only a few published studies on growth in human vegetarian children. The available studies suggest that diets described as "vegetarian" are associated with slightly restricted growth. These studies are summarized in Table 2. Although they suggest that a vegetarian diet is related to depressed growth, alternative explanations must also be considered. First, most studies severely confound dietary content with total number of calories. In fact, nearly all of the
TABLE 2

<table>
<thead>
<tr>
<th>Study</th>
<th>Sample</th>
<th>Height differences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dwyer et al. (51)</td>
<td>142 vegetarian and 229 nonvegetarian children</td>
<td>Vegetarian children were 1-2 cm shorter</td>
</tr>
<tr>
<td>Sanders and Purves (56)</td>
<td>23 vegan children</td>
<td>Children were within normal range for height; but there were more children below the 50th percentile rank (DHS standards)</td>
</tr>
<tr>
<td>Dwyer et al. (60)</td>
<td>39 preschool children on various vegetarian diets</td>
<td>80% of the children were below the 50th percentile for height (NCHS standards)</td>
</tr>
<tr>
<td>Shull et al. (53)</td>
<td>72 vegetarian children</td>
<td>Children &lt;2 years old were below normal height standards</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Children &gt;2 years old were in the normal range for height (Harvard Study standards)</td>
</tr>
<tr>
<td>Trahms and Feeney (55)</td>
<td>Children who changed from a pure vegetarian diet to a less restrictive diet</td>
<td>Mean height increased from the 4th to the 41st percentile over a 2-year period</td>
</tr>
</tbody>
</table>

studies focus on diets that provide undernourishment in nutrients. Thus, undernourishment serves as an alternative explanation for any observed growth restriction. It is important that all vegetarian diets not be considered equal. Current recommendations are to reduce total fat consumption to 30% of calories. Some of the extreme vegetarian diets include as few as 10-20% calories from fat. Findings from these extreme diets should not be extrapolated to more prudent recommendations. In addition, variables unrelated to diet may account for the depressed growth of the vegetarian children. For example, the differences may be a function of differential morbidity, utilization of medical services, poverty, and genetics.

Another serious methodological problem is that none of the studies included long-term follow-up. This makes projections about the future health status and growth of vegetarian children difficult. Some studies suggest that there may be a delay rather than an arrest of growth. The one study (58) in which the authors concluded that growth of vegetarian children does not catch up to the normal population was based on cross-sectional data. The use of such data to make claims about catch-up growth is weak at best.

A related issue has to do with the developmental stage of the children under study. Children in these studies range from late infancy to preschool years. As Jacobs and Dwyer (58) point out, both height and weight differences, but particularly height, are most affected in the early stages of growth in children raised on extreme vegetarian diets. They further reported that catch-up growth occurs during the preschool years for some of the children. Beyond preschool, there were
few studies that followed the growth pattern of these children. This would seem particularly important in adolescence when significant increases in nutritional requirements are necessary for the pubertal growth spurt. Current recommendations exempt children below the age of 2 from fat restriction because of concerns about growth (5–7).

A final methodological consideration involves subject recruitment. A majority of the samples were relatively small and represented a self-selected group of children. In the original Dwyer et al. (60) study, only 26 children from a roster of 133 vegetarian families agreed to participate in the study. The remaining 13 children in the study were voluntarily provided by an East–West foundation group concerned with promoting macrobiotic diets as a nutritional alternative. These self-selected groups of children were then compared to a "normative" group, in some instances national averages and in others a group of nonvegetarian children. Some of the studies did not adequately control for age or sex. Thus, the validity of the data and the conclusions one can draw from them are restricted.

In summary, the evidence suggests that children with any reasonable amount of animal protein in the diet may experience more growth than those deprived of animal protein. Most current studies do not allow the separation of animal fat from other nutrients. At present, we know very little about the shape of the function relating diet to growth potential and have not identified the threshold needed for optimal growth.

DOES CHILDHOOD DIETING CAUSE STUNTED GROWTH?

If dietary fat exposure stimulates growth, then restrictions in dietary fat may slow growth velocity. Concerns about these issues have surfaced in a series of recent articles. In one paper, Pugliese and colleagues (61) evaluated 201 children with short stature, delayed puberty, or both. Among these, they identified 14 who had gone on a self-imposed dietary regimen because of a fear of obesity. Half of the children who dieted had delayed puberty, and 11 of the 14 were below the fifth percentile in height. All were below the fifth percentile in weight. Most of the adolescents had deviated from their expected growth patterns (based on tracking charts). After identification, the adolescents were "treated." Treatment involved nutritional counseling to promote weight gain. The adequacy of treatment was reported as an increase in linear growth the year after treatment, as compared to the year before. However, the evaluation of the treatment was confounded by expectation of the adolescent growth spurt. Although intriguing, the Pugliese paper is difficult to evaluate because the participants were highly selected and there was no evaluation of control adolescents who may have had similar diets. This study is focused on subjects selected because they had failed to grow and it is possible that others on the same restricted diets may have experienced normal growth. Similarly, variability in growth and onset of puberty is expected within any population and the cause/effect relationship in this case is difficult to assess.

A second paper from the same group of investigators attributes failure to thrive to parental health beliefs (11). The subjects were seven patients between the ages of 7 to 22 months of age. The children were referred to specialists because of
inadequate weight gain and linear growth. Upon examination, it was concluded that they were consuming between 60 and 94% of the expected caloric intake for age and sex. Interviews with parents identified concern about obesity, atherosclerosis, and junk food dependence as the basis for the restricted diets. With nutritional counseling, all of the children gained weight and increased linear growth. The authors blamed parents, who were over concerned about heart disease and obesity, for their children’s growth failure.

Although the second Pugliese study raises interesting questions, it has serious flaws as a research investigation. First, the participants were highly self-selected and there were no controls. We do not know, for example, the rate of failure in linear growth for all children given the same diet. It is difficult to evaluate the relationship between dietary practice and growth without knowing the variability in each variable for the entire population. A second concern is that the data were not collected in a formal way. The paper only suggests that an unstructured interview revealed that parents were concerned about creating "junk food addicts" (p. 176). In addition, the role of interviewer expectations was not taken into consideration.

A more recent paper by Lifshitz and Moses (62) evaluated 8 children who are undergoing an unsupervised dietary treatment for hypercholesterolemia. Among 40 children on unsupervised regimens, these 8 experienced some problem: 5 experienced significant weight loss while 3 children deviated from expectations on growth charts. As in the other papers by Pugliese and Lifshitz, growth failure was defined as deviation from an expected value based on growth charts. These papers do not take into consideration expected variability in growth over the course of time. Thus, there is no statistical test to evaluate how much deviation is considered "significant." However, considering percentile variations, the differences appear to be of concern. Analysis of food consumption by those with growth failure suggested that they consumed only 66% of the energy requirements and only 40% of their daily zinc requirements. The paper suggests that those on low-fat diets with normal growth consume 80% of their energy requirements and 58% of their zinc requirements. The 3 children who had more serious dwarfing consumed only 20% of their calories in fat while those with more normal growth consumed closer to 30%. Unfortunately, the very small number of patients with stunted growth makes statistical comparisons difficult. Again, it is very difficult to evaluate these data without knowing the distribution of fat consumption and growth in the general population. Again, we caution the reader from extrapolating results from these extreme dietary deviations to the modest changes recommended by professional groups.

A third report considered height velocity changes as a function of weight reduction in preadolescents (63). In this study, 19 obese children were selected because of a 10% or greater fall in weight relative to height. Although the subjects were described as preadolescents, they ranged in age from 2.6 to 12.7 (mean = 8.5 years). The subjects tended to be obese (mean = 162% of ideal body weight) at the beginning of the study. All of the children were subjected to a diet designed to reduce body fat. The children lost an average of 4.5 kg, resulting in an average weight loss of 29% of ideal body weight. Height velocities were reported in Z
scores, representing an adjustment for expected height change in each age and sex grouping. Prior to weight reduction, the average height velocity was 2.32 Z scores. In other words, this group of children was at approximately the 99th percentile of the distribution in their rate of increase in height. After weight reduction, they decreased to a Z score of 0.62 which placed them near the 73rd percentile for rate of increase in height. There was a significant linear relationship between amount of weight lost and rate of decline in height velocity. The authors concluded that strict monitoring of weight maintenance programs for children is indicated. Although these results are very interesting, several issues must be considered in order to place them in perspective. First, as with the Pugliese and Lifshitz studies, this investigation involved self-selected groups of children. Interestingly, this group of children was very big to begin with. The Z scores for height velocity were, on average, in the 99th percentile of the distribution, with one child eight standard deviations above the mean and another nearly seven standard deviations above the mean! If these velocities continued through adolescence, these children would literally become giants. For example, a 10-year-old girl in the study entered with a height of 164 cm. It is not entirely clear that all of the changes were due to weight reduction and not to regression to the mean. Nevertheless, the Dietz and Hartong study is an interesting one that raises important questions for further investigation.

Epstein et al. (64) evaluated the long-term effects of weight loss programs on children. This study differs from the others that have been reviewed because the investigators followed the children prospectively. In addition, the nature of the dietary intervention was well controlled. Growth was evaluated by comparing each child against standardized age and sex norms for height. In addition, expected values based on parental height were also considered. At baseline, the children in this weight loss program tended to be tall (mean percentile = 72 for the respective age/sex distributions). In addition, prior to treatment, the children were taller than would be expected based on parental heights. After participation in a 5-year weight loss program, the children were shorter than would have been expected given their pretest heights, but still taller than what would have been expected given their parents' heights. Those children of the tallest parents were the exception, ultimately coming to resemble parental heights.

In summary, some studies have linked dietary restriction to slowed growth in children. These changes in growth velocity have been attributed to reduced fat in the diet. However, the reduced animal fat hypothesis has not been tested directly and studies have not been designed to separate the effects of fat restriction from the effects of reductions in other nutrients or from reductions in total calories.

*Delay versus Deviance*

It is not known whether reductions in height following dietary change represent a retardation of growth or permanent growth stunting. Some of the studies [i.e. (61)] imply that dietary restrictions delay the onset of puberty. The adolescent growth spurt for females peaks approximately 1 year prior to the onset of menses (menarche). In the United States, the age of menarche has been decreasing at a
rate of about 3 to 4 months per decade over the last century (65). A body weight of an estimated 48 kg is believed to be the critical stimulus for onset of menses with obese girls menstruating at an earlier age than their normal-weight classmates. Evidence does suggest that dietary restrictions can delay the onset of this process. But is this a matter of major concern? Although normal weight females have a later onset of menses, there is little evidence that the onset never occurs, except for in the most severe cases of body fat reduction.

As with the onset of puberty, it is unclear from the literature whether studies have witnessed a delayed maturation or deviant maturation resulting in ultimate short stature. Several studies have implied that there is no catch-up among children who have had delayed growth (58, 61). Unfortunately, studies in the literature fail to follow participants into adulthood. Thus, there is little evidence suggesting that children do or do not catch up. One hypothesis is that there is a predetermined genetic program and that nutrition is required to achieve the ultimate height. If only 50% of the calories are available, achieving the ultimate height may take twice as long. Thus, obese children may achieve their ultimate height at an earlier age but may not necessarily be taller as adults. Some evidence goes against this theory. For example, obesity and height are correlated in adults.

Some of the most interesting observations related to the delay versus deviance issue were obtained in a unique data set from the 19th century that was recently re-discovered. In 1884 Sir Francis Galton established an anthropometric laboratory in London where remarkably detailed measures of body characteristics were taken. Many of the data obtained in these studies were never analyzed and were discovered nearly a century later by Johnson and colleagues (66). One of the most interesting observations was that there were differences in socioeconomic status (SES) for height during the adolescent years. In particular, the professional classes were significantly taller by age 14. In the 19th century, the higher social classes were the most likely to obtain adequate calories. However, growth continued for some individuals until the mid-1920s. Some of the results from Johnson's reanalysis of the Galton data are presented in Fig. 1. As the figure demonstrates, the professional classes were significantly taller at age 14. By age 16, the merchant and semiskilled classes had caught up, with the boys from the unskilled families still being significantly shorter. By age 18, these lower SES boys caught up. Interestingly, the boys from the managerial families experienced no height increase between ages 22 and 24 while there was a slight increase from those in the other three social classes. It is important to emphasize that these observations are based on cross-sectional rather than longitudinal data.

Similar observations were provided by Oppers (67) who found records taken on repeated observations of the same individuals in Holland during the 19th century. Oppers estimated that between the years 1820 and 1880 the average height gained between age 18.75 and full maturity was 7 cm. By the year 1990, the average late growth was 5 cm and by 1960 was down to 2 cm. The data from these studies do suggest that slow growth, perhaps associated with deficient calorie exposure, may also be associated with a prolonged growth period. Ultimately, median adult heights observed in different social classes represent less variation than do those observed in adolescence.
DO REDUCED FAT DIETS INHIBIT GROWTH?

Substantial evidence does suggest that dietary supplementation for food-deprived children does enhance growth. For example, Mora and colleagues (68) supplemented the diets of poor children in Bogota, Columbia. The supplementation started at birth and the children were followed through 36 months of age. Food supplements consisted of powdered skim milk, cooking oil, and enriched bread. By age 3, there was a significant difference between those receiving the supplement and the control group, although the differences were small. Another report on the same 280 Columbian infants suggested that food supplementation enhanced growth by 2.6 cm at age 3. Home visitation, in addition to food supplementation, reduced the number of short children further when assessed at age 6 (69).

As reported earlier in this paper (33), anthropometric measurements revealed that nearly 50% of Indo-Chinese refugee children were two standard deviations below the mean of a U.S. reference group. When compared to Thai reference scales, 20% of the children were still two standard deviations below the mean. These results have prompted others to investigate the causes of growth retardation in refugee village children. Gershoff and colleagues (70) studied 2,250 children, ages 1.5 to 9 years, to assess the effects of dietary supplements on the growth and development of children in Chang Mai, Northern Thailand. The children were divided into one of the five groups: (a) a control group with no interventions; (b) a sanitation–health program; (c) a day-care center; (d) a free vitamin–mineral supplement, day-care center, and sanitation–health program; and (e) a
vitamin–mineral supplement, day-care center, sanitation–health program, and high calorie snack. Over a 2-year period there were no significant effects of the interventions on the height or the weight of the children, and there were no differences between the various experimental groups in growth rates. In general, the village children were significantly shorter and lighter than Thai children from middle-class families at baseline and after 2 years of intervention. Over the years, studies have claimed that food supplements/nutrient supplements in cases of nutrient deficiencies in small children result in small but significant increases in growth. Evidence from this study and a comprehensive review by Beaton and Ghassemi (71) suggests that supplemental nutrition programs in developing countries have small, if any, effects on anthropometric measurements. However, SES has a major impact upon attained weight (72).

This study raises questions about the interrelationship between diet and height/weight measurements of children with depressed growth. The factors that control growth in this subgroup are obviously not well understood. Thus, intervention programs, though helpful in preventing malnutrition and related diseases, do not seem to relieve retarded growth in these children. Several hypotheses may help to explain the seeming discrepancy. It is possible that nutritional requirements during certain crucial stages of development must be met in order to ensure optimal growth. In such large-scale studies it is difficult, if not impossible, to account for the developmental stage of each child in assessing his or her nutritional requirements. Further research is needed to determine if and when critical periods of vulnerability exist. It is possible that nutritional requirements are not immediately recognized and may require longer than 2 years to emerge. An equally plausible explanation is that the nutritional supplementation was too weak to produce measurable effects. Understanding the relationship between diet and growth, particularly in children with depressed growth, is a rich area for research since relatively little is known at this time.

CONCLUSION

In summary, there has been considerable interest in low fat and vegetarian diets as vehicles to reduce the burden of (CHD). Evidence for effects of fat restriction upon short stature comes from studies of secular trends, migration, weight reduction, and vegetarian communities. Some groups have challenged the use of low-animal-fat diets for children, arguing that reduced fat consumption will result in stunted growth. Our review of the literature suggests that many questions remain unanswered. Although there is suggestive evidence that fat-restricted diets are related to slowed growth, nearly all the studies have methodological problems that limit the generalizability of the findings. The most common problem is that dietary fat is confounded with total calories and other nutrients. Thus, very few studies have separated the effects of fat reduction from the effects of undernourishment. Recommendations offered by the American Heart Association, the National Cancer Institute, the National Cholesterol Education Program, and the American Health Foundation call for a redistribution of calories so that only 30% of the total caloric intake comes from fat. In no way did any of these groups recommend severe dietary restriction. None of the groups have advocated radical dietary
alterations. After reviewing the evidence on vegetarian diets, Jacobs and Dwyer (59) suggested that lactovegetarian, and semivegetarian eating patterns conform with recommendations for reducing risk of chronic illnesses without posing serious risks for growth and development. More radical vegan diets, when used early in life, may pose nutritional deficiencies that could potentially disrupt growth for infants and small children. It is important to emphasize that no formal consensus committee has endorsed these more radical diets. An important issue for future debate is the value of height. Tallness is not necessarily an indicator of health or a healthier lifestyle. Height may even be an indicator of over nutrition, which in turn creates risk for poor outcomes later in life.

A variety of other methodological issues need further investigation. Our review suggests that most studies include small sample sizes or participants that may not be representative of the general population. Many studies have no control or comparison group. For example, clinical studies often identify vegetarian children who failed to grow but do not include growth records of other children on the same diet. Few studies are longitudinal in nature, and few studies consider probabilities of growth failure as a function of dietary restriction in comparison to growth variability in the general population. Finally, more attention should be paid to critical stages of growth. The available evidence does not clearly identify a critical period for animal protein consumption, but does imply few risks of exposure to prudent levels of animal proteins during childhood. The available literature fails to distinguish growth deviance (permanent growth stunting) from growth delay. It is possible that dietary fat plays an important role in growth at some stages of development but not at others. Although investigation in this area is difficult, more rigorous research is needed.

Studies of the effects of dietary intervention in children have important policy implications. Currently, several organizations are recommending alterations in the U.S. diet. The Committee on Nutrition of the American Academy of Pediatrics has taken the most conservative position on reduction of dietary fat. Although the academy recommended a prudent diet, their position was a courageous break from the positions taken by other groups. The difference in recommendations creates confusion for the practicing pediatrician, dietician, and parent. On the basis of current evidence, it is very difficult to determine which position is correct. However, all groups agree that modest reductions of saturated fat are appropriate. Again, we encourage future research to help inform the development of a consensus policy in this area.

To summarize, there is little conclusive evidence for or against the hypothesis that reduced fat diets harm children. However, the evidence that they are helpful before the third decade of life is also ambiguous. We concur with the recommendation of a prudent diet for children and that choice of diet must be guided by personal preference until more scientific evidence is available.

REFERENCES
45. Thompson WG. Practical Dietetics: With Special Reference to Diet and Disease. 2nd ed. New York: Appleton, 1903.

Received August 8, 1990
Revised May 8, 1991
Accepted May 8, 1991