Growth of Vegetarian Children: The Farm Study

Joan M. O'Connell, MHS, Michael J. Dibley, MB BS, Janet Sierra, RN, Barbara Wallace, PhD, James S. Marks, MD, MPH, and Ray Yip, MD, MPH

From the Division of Nutrition, Center for Health Promotion and Education, Centers for Disease Control, Atlanta, Georgia, and The Farm, Summertown, Tennessee

ABSTRACT. To examine the effects of a vegetarian diet on child growth, height and weight data of 404 vegetarian children aged 4 months to 10 years who lived in a collective community in Tennessee were studied. Height for age, weight for age, and weight for height were compared with the US growth reference. Birth weights, infant feeding patterns, and parental heights were also evaluated in relation to growth. Most of the height for age, weight for age, and weight for height (n = 833) were within the 25th and 75th percentiles of the US growth reference. The mean height for age and weight for age, however, were slightly less than the median of the reference population. For different age groups, the mean height ranged from 0.2 to 2.1 cm and the mean weight ranged from 0.1 to 1.1 kg less than the reference median. The largest height difference was observed at 1 to 3 years of age and may be partly the result of intrinsic irregularities in the US growth reference at those ages. By 10 years of age, children from The Farm averaged 0.7 cm and 1.1 kg less than the reference median, representing only 0.1 and 0.3 SD from the reference. Thus, these children have adequate attained growth, even though it was modestly less than that of the reference population. *Pediatrics* 1989;84:475–481; *vegetarian diet, growth, height, weight, birth weight.*

To examine the effect of a vegetarian diet on child growth, we studied height and weight of a group of infant and vegetarian children ages 4 months to 10 years. The growth of children consuming vegetarian diets was of interest because of the number of children consuming such diets and the special dietary needs of children during periods of rapid growth. It has been reported that approximately 4 percent of adults in the United States consume vegetarian diets.[1] Worldwide, many ethnic groups have followed vegetarian diets for centuries. The reasons people adhere to these diets include religious, ethical, political, and health beliefs and economic constraints.[1–7]

Although several investigators have addressed the issue of the growth of vegetarian children, most of these studies were based on relatively small numbers (50 or fewer) of preschool-aged children.[8–20] Aside from the small numbers, drawing conclusions from these studies is somewhat difficult because of the variety of health-related beliefs and life-styles of the study populations and the dietary differences of the study populations. For example, some vegetarians have behaviors concerning vitamin and mineral supplements and conventional medical care that differ from those of the general population.[8,20–22]

The types of vegetarian diets consumed by the studied populations must be considered when interpreting results of the growth studies. The extent to which vegetarian diets meet dietary recommendations varies greatly[17–33] because the term vegetarian refers to a broad dietary group of people who avoid meat in their diets. It is estimated that 90% of the vegetarians in the United States are lacto-ovo-vegetarians, who include milk and dairy products in their diets.[1] Vegans are vegetarians who avoid all animal products, including milk and dairy products. There exist additional types of vegetarian diets, some of which involve further restrictions on dietary intake. Although it may be more difficult to provide adequate diets for children with restricted protein intake compared with children who have no restrictions, all necessary nutrients, including vitamins B_{12} and D, calcium, iron, and zinc, can be provided with careful planning.[18,19,28–33]

To examine the effect of a vegetarian diet on child growth, in this study we describe the growth of vegan children who lived in a collective community in Tennessee. In this community, the children

Received for publication Jun 13, 1988; accepted Oct 11, 1988.
Reprint requests to (R.Y.) Centers for Disease Control, Division of Nutrition, Mail stop A-41, Atlanta, GA 30333.

followed a similar diet and many received vitamin and mineral supplements. Because growth data were collected annually, there was available for study a relatively large number of measurements of children through ten years of age. In addition, we evaluated birth weights, parental heights, and breast-feeding patterns in relation to growth.

SUBJECTS

The children lived in a community called The Farm, located in rural central Tennessee. The Farm was established in 1971 as a collective community that met many of its own needs concerning health care, education, housing, and, to some extent, food production. The socioeconomic level of the population of The Farm was unusual in that the community members were highly educated, but they generated a comparatively small income from sources outside the community. The average family income was below the federal poverty level for many years but gradually increased over time. The majority of the children were white and had lived on The Farm since birth.

The Farm community was generally well informed regarding issues related to vegetarianism, including complementing different protein sources, for example, grains and legumes and nonanimal sources of vitamins and minerals. Until 1983, the population followed a vegan diet, with soybeans being their primary source of protein. Supplements of vitamins A, D, and B_{12} were added to the soy milk produced on The Farm. Nutritional yeast (containing vitamin B_{12}) and other vitamin and mineral supplements were also used. In the fall of 1983, some members of the community introduced eggs and dairy products into their diets.

METHODS

1984 Special Growth Survey

In the spring of 1984, we collected height and weight data of 144 children residing on The Farm. We obtained written parental consent from more than 95% of the families. In addition, a few children were excluded from the study because of ethnic, dietary, and health backgrounds that differed from the other children raised there or because they had a chronic illness known to affect their growth.

Body length to the nearest millimeter was determined with a measuring board for children younger than 2 years of age; standing height was measured for older children. We measured their weight to the nearest 28 g (1 oz) with a Detecto pediatric balance for children less than 2 years of age and to the nearest 112 g (quarter pound) with a beam balance for children older than 2 years of age. At the same time, a subset of the population was measured on separate days to validate measurement techniques; no systematic errors were found.

The Farm's Annual Growth Surveys

In addition to the data collected in the 1984 special growth survey, we included growth data from the annual growth surveys of The Farm in our analyses. Height and weight data from four cross-sectional surveys performed in the years 1980 to 1983 were included. ETHOS, a Farm research organization, and The Farm's health clinic conducted the annual surveys because members of The Farm community were interested in the physical growth of their children.

The methods used in the 1980 to 1983 growth surveys were not subject to the same rigor as the 1984 special growth survey. We evaluated several characteristics of the earlier surveys to determine the reliability of those data and to determine the suitability of combining the data from The Farm annual surveys with the data from the 1984 survey for cross sectional analyses.

To determine the reliability of the data collected in each of the separate cross-sectional surveys, we compared height for age, weight for age, and weight for height data between the 1984 special survey and the annual growth surveys of The Farm. No significant differences were found. Because the surveys were conducted at the same time of year, children with multiple measurements in the data set were not represented more than once in the age group breakdowns by year. We found no significant differences in growth, dietary, or demographic data between children who had multiple measurements with those who had only one measurement and between children measured in 1984 and children measured in the earlier Farm surveys. Based on these analyses, all survey data from 1980 to 1984 were combined into one data set.

Dietary, Health, and Demographic Data

To supplement the growth data, we extracted self-reported information from two health surveys conducted by ETHOS on The Farm in 1980 and 1983. The information included birth date, dietary history, birth weight, parental height, breast-feeding patterns, vitamins and mineral supplementation, and place of birth. We also obtained disease histories for each child to determine whether any children had disorders of nutritional significance that might cause their exclusion from the study.

We evaluated the reliability of the data reported in the 1980 and 1983 health surveys. If data existed

for a child from both surveys, the information was cross-checked for consistency of reporting. No significant differences were found in data reported in 1980 and 1983. We collected recent dietary histories in 1984 to update past survey data.

The dietary data provided in the health surveys were "modified food frequencies" by year and included the mother's diet during pregnancy. We classified the children as omnivore (nonvegetarian), lacto-ovovegetarian, or vegan for each year based on the amount of eggs, dairy products, and meats reported in their diets. We analyzed growth in relation to the following diet classifications: the mother's diet during pregnancy, the child's diet from birth to age 2 years, and the child's diet during 1984. We were also interested in whether or not the child had followed a vegan diet since birth.

For each child, we averaged the heights of the mother and father for a mean parental height.[34,35] We then compared The Farm mean with the average of the mean heights of 25-year-old men and women from a US reference population.[36]

Statistical Procedures

We compared weight and height measurements of the children to the National Center for Health Statistics/Centers for Disease Control growth reference population by age and sex. A growth percentile rank was calculated for each set of measurements for three growth indicators: height for age, weight for age, and weight for height.[37] We regarded a percentile value greater than the 95th percentile or less than the 5th percentile as abnormal growth. For each set of measurements, a standard deviation value, Z score, was calculated for each growth indicator based on the growth reference; a Z score of +1.0 represented 1 SD greater than the mean of the reference population.[38,39] The Z scores were then compared by age group with the reference median (presumed mean). We compared the mean Z scores of the growth data after stratifying them by mean parental height, birth weight, sex, and diet. We used Student's t tests and analysis of covariance to determine the significance of these variables in relation to growth.

RESULTS

We evaluated anthropometric data and health data for 404 white children, who had a total of 833 measurements. The mean age at the time of measurement (n = 833) was 71.6 months; 7.7% of the children were less than 2 years of age; 35.7% were 2 to 5 years of age, and 56.7% were 6 to 10 years of age. In Table 1, additional social, demographic, and dietary information are provided. The mean birth

TABLE 1. Social, Demographic, and Dietary Data of The Farm Children

Item	No. (%) of Children*
Birth data	
Born on The Farm	304 (82)
Lived on The Farm by 2 y of age	339 (91)
Birth wt <2500 g†	18 (5)
Infant feeding patterns	
Breast-fed‡	335 (95)
Solid foods started by 6 mo of age§	121 (80)
Other dietary information	
Mother's diet during pregnancy	
Vegan	281 (75)
Lacto-ovovegetarian	64 (17)
Omnivore	28 (8)
Child's diet	
Birth–2 yr of age	
Vegan	288 (83)
Lacto-ovovegetarian	49 (14)
Omnivore	11 (3)
Vegan since birth	253 (73)
Vitamin/mineral supplementation	263 (76)
Regular yeast supplementation	139 (87)

* Based on available data.
† Mean birth weight 3389 g.
‡ Mean number of months breast-fed was 12 months.
§ Mean age when solid foods were introduced was 5 months.

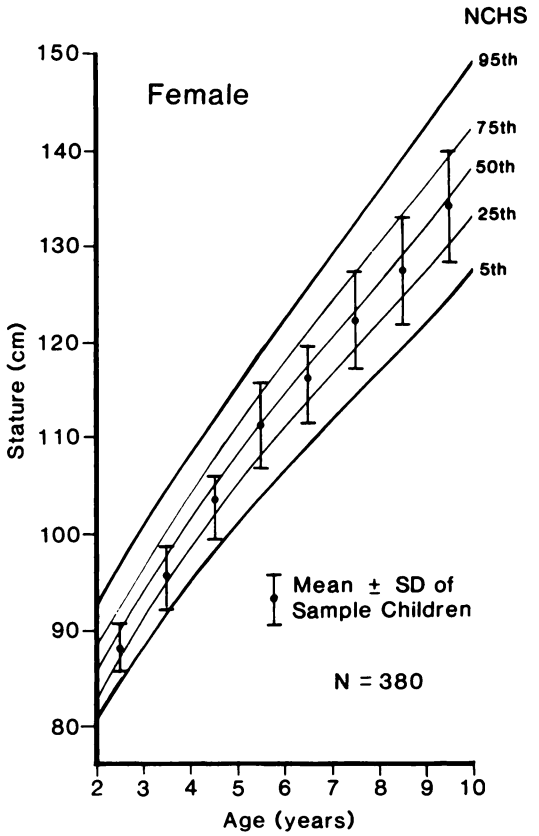

Fig 1. Height for age of girls from The Farm relative to National Center for Health Statistics (NCHS)/Centers for Disease Control percentiles.

weight of The Farm children was 3389 g; the percentage of low birth weight infants (<2500 g) was 5%. These statistics were similar to birth weight statistics for well-educated US white women.[40] The mean parental height of The Farm children was 172.6 cm, compared with 170.4 cm, the average of the mean heights of 25-year-old men and women from the reference population.

Height for age, weight for age, and weight for height Z score data are depicted in Figs 1 to 6 for ages 2 to 10 years. Overall, the distributions of the height for age, weight for age, and weight for height of children from The Farm were between the 25th and 75th percentiles of those of the reference population for most ages. In Table 2, the differences between The Farm growth data and the reference population growth data are shown (in centimeters and kilograms) for all ages. The mean Z scores of The Farm height for age and weight for age data were less than the median (presumed mean) of the reference population for most ages. In general, the differences in height for age Z score between The Farm and the reference population are statistically significant for ages 5 years and younger. The greatest differences were seen at ages 1 to 3 years, with a decrease at older ages. However, the height for age differences are not significant for ages 5 years and older. Overall, data of 8% of The Farm children were less than the 5th percentile of the height for age reference.

The Farm weight for age data were slightly less than those of the reference population for most ages. The weight for age Z scores were only statis-

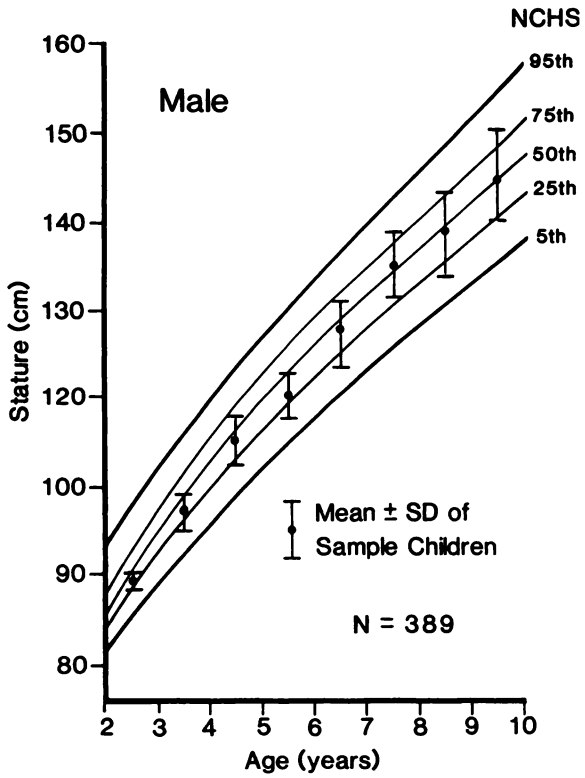

Fig 2. Height for age of boys from The Farm relative to National Center for Health Statistics (NCHS)/Centers for Disease Control percentiles.

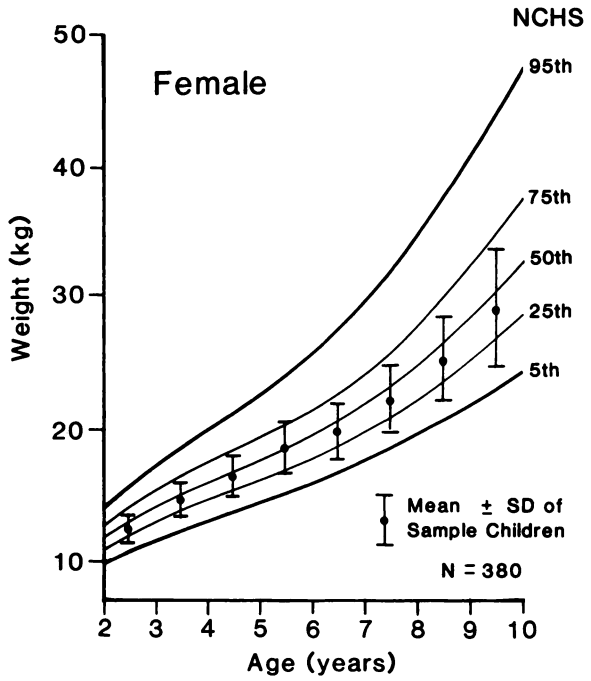

Fig 3. Weight for age of girls from The Farm relative to National Center for Health Statistics (NCHS)/Centers for Disease Control percentiles.

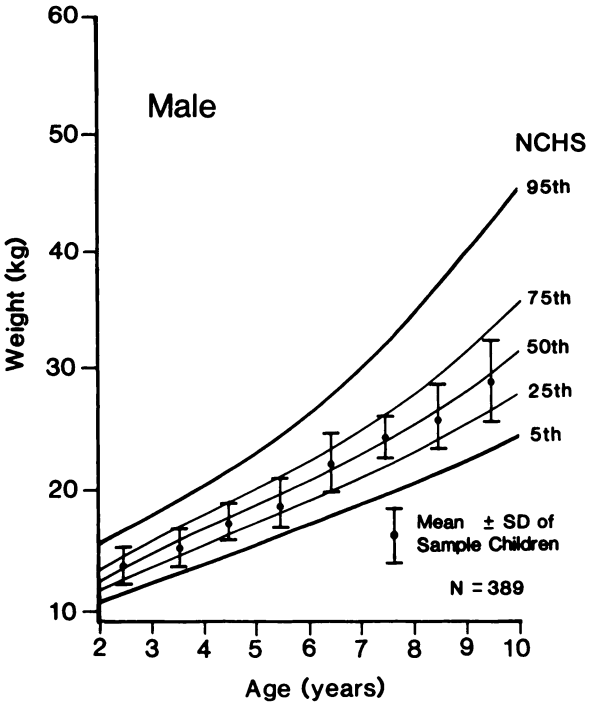

Fig 4. Weight for age of boys from The Farm relative to National Center for Health Statistics (NCHS)/Centers for Disease Control percentiles.

tically significant at ages 9 and 10 years. Of The Farm children, 3% were less than the 5th percentile of the weight for age reference. The Farm weight for height data were slightly greater than those of the reference population for most ages. The differences in weight for height were statistically significant at ages 5 and younger and at age 9 years. Of The Farm children, 1% were classified as small weight for height (weight for height < 5th percentile) and 3% as large weight for height (weight for height > 95th percentile).

A positive association existed between mean parental height and the height for age Z scores ($P < .0001$). The difference in height for age between children from The Farm and the reference population children decreased with age ($P < .0001$). We stratified the data by sex, diet, and birth weight after controlling for age and parental height. The growth patterns were similar for the different stratifications.

DISCUSSION

In this study, the growth of a group of children raised with a relatively strict form of vegetarian diet (vegan) was similar to that of the reference population, even though the mean height for age and weight for age were modestly less than the median of the reference. The differences between The Farm and the reference population were greater for the height for age indicator than for the weight for age indicator,with the greater differences in height for age between 1 and 3 years of age. By

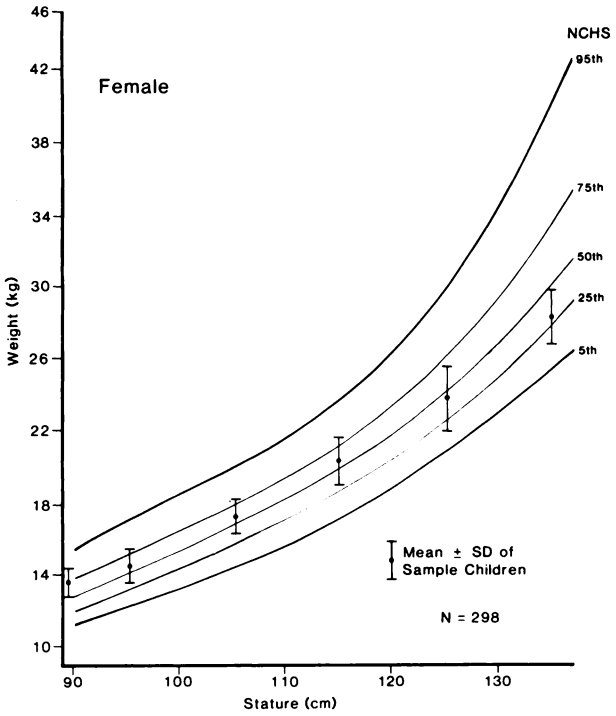

Fig 5. Weight for height of girls from The Farm relative to National Center for Health Statistics (NCHS)/Centers for Disease Control percentiles.

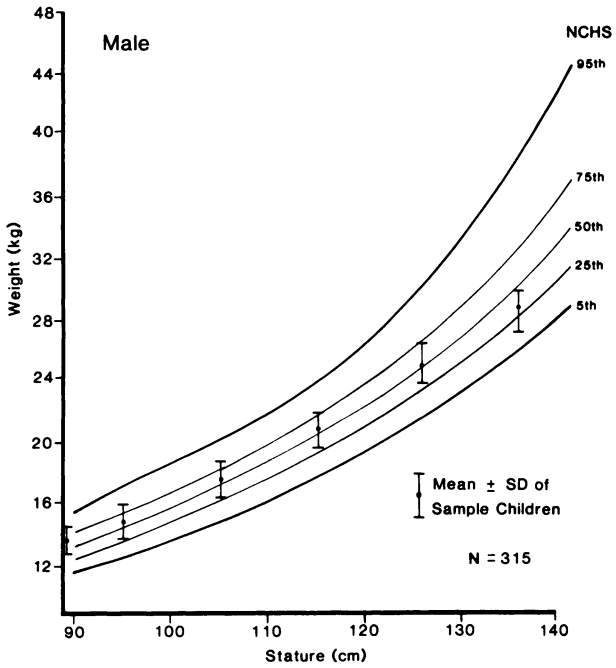

Fig 6. Weight for height of boys from The Farm relative to National Center for Health Statistics (NCHS)/Centers for Disease Control percentiles.

TABLE 2. Differences in Height and Weight Between The Farm Children and the National Center for Health Statistics/Centers for Disease Control Growth Reference Population (n = 833)

Age (y)	Height		Wt	
	Difference From Reference (cm)	Farm Mean Height for Age Z Score	Difference From Reference (kg)	Farm Mean Wt for Age Z Score
<1	−0.24	−0.09	−0.09	−0.10
1–2	−2.01	−0.67	−0.10	−0.09
3–4	−2.06	−0.55	−0.20	−0.13
5–6	−1.76	−0.39	−0.37	−0.18
7–8	−0.69	−0.13	−0.16	−0.06
9–10	−0.67	−0.11	−1.11	−0.27

10 years of age, the vegetarian children averaged within 0.7 cm and 1.1 kg of the reference population, representing 0.1 and 0.3 SD from the reference. The Farm children experienced normal birth weights, a finding previously reported for The Farm population by Carter et al[41] and for other vegetarian populations.[17,18]

In past studies,[13–20] the growth of vegetarian preschool children has been shown to be somewhat lower than that of reference populations yet within normal growth limits, with length being more affected than weight. However, in some of the past studies,[13,18] a greater proportion of children was shown with small height for age and weight for age (<5th percentile of the reference). In other studies,[14–16] statistically significant growth differences were also described among certain age groups, such as weaning age, and for children with very restricted diets. Weight for height data[13] have been described as being within normal expectations. Anthropometric studies of adult vegetarians, however, have shown no significant differences in the heights and weights of the vegetarians when compared with control subjects.[3,21]

Although, at younger ages, The Farm children's height for age *Z* scores were significantly less than those of the growth reference population, there are a few possible explanations for the smaller height for age status. The first possibility involves the introduction of solid foods into a child's diet. Several researchers[13–16] have shown significant differences in weights and heights at weaning age for vegetarian children when they were compared with reference populations. Weaning foods in some vegetarian diets may have low caloric densities; therefore, some vegetarian children may not consume enough calories for normal growth during weaning.[17] The age at which solid foods are introduced has been also noted as a factor influencing growth. For this study population, appropriate solid foods were introduced in the diets of most of The Farm children by 6 months of age. However, because of the low income level of the residents of The Farm in the early years of its existence, the variety of foods available during certain seasons was limited and may have adversely affected the diets of children who were 2 years of age or younger at that time.

The second possible explanation for the growth variations between the study population and the reference population is that the reference population consisted largely of bottle-fed infants with early supplementation, whereas The Farm infants were breast-fed, with solid foods introduced at an average age of 5 months. No growth reference is available specifically for breast-fed children. Available data suggest,[42,43] however, that breast-fed infants may have somewhat slower growth patterns when compared with bottle-fed infants with early supplementation.

The third, and perhaps the most important, possible explanation for the differences between The Farm and the reference population involves the intrinsic irregularities in the current reference growth curves. The National Center for Health Statistics/Centers for Disease Control reference consists of two populations (the Fels data of children from Yellow Springs, Ohio, for ages 0 to 24 months and the US representative data for 2 years of age and older), with noted differences in height between the two populations.[44,45] If the reference population were free from these irregularities, the observed differences in height for age between the study and the reference populations would be smaller at the younger ages.

In summary, the growth of The Farm children even though modestly less than that of the reference population, showed no evidence of marked abnormality. Part of the growth differences observed at younger ages may be related to the limitations of the current growth reference. According to the results of this study, with attention to weaning foods and nutrient intake, a group of children raised with a relatively strict vegetarian diet (vegan) can achieve adequate growth.

ACKNOWLEDGMENT

We thank The Farm community, ETHOS, and the Ruth Mott Fund for their assistance in the study.

REFERENCES

1. Roper Report 78-10, October/November 1978. Storrs, CT: Roper Center for Public Opinion Research, University of Connecticut
2. Ophir O, Peer G, Gilad J, Blum M, Auiram A. Low blood pressure in vegetarians: the possible role of potassium. *Am J Clin Nutr.* 1983;37:755–762
3. Armstrong B, Van Merwyk AJ, Coates H. Blood pressure in Seventh-Day Adventist vegetarians. *Am J. Epidemiol.* 1977;105:444–449
4. Harding MG, Stare FJ. Nutritional studies of vegetarians. 2. Dietary and serum levels of cholesterol. *Am J Clin Nutr.* 1954;2:83–88
5. Wiseman MJ, Hunt R, Goodwin A, et al. Dietary composition and renal function in healthy subjects. *Nephron.* 1987;46:37–42
6. Howie BJ, Shultz TD. Dietary and hormonal interrelationships among vegetarian Seventh-Day Adventists and nonvegetarian men. *Am J Clin Nutr.* 1985;42:127–134
7. Dwyer JT, Kandel RF, Mayer LDVH, Mayer J. The "new" vegetarians. *J Am Diet Assoc.* 1974;64:376–382
8. Bachrach S, Fischer J, Parks J. An outbreak of Vitamin D deficiency rickets in a susceptible population. *Pediatrics.* 1979;64:871–877
9. Robson JRK, Konlande JE, Larkin FA, et al. Zen macrobiotic dietary problems in infancy. *Pediatrics.* 1974;53:326–

329
10. Higginbottom MC, Sweetman L, Nyhan WL. A syndrome of methylmalonic aciduria, homocystinuria, megaloblastic anemia and neurologic abnormalities in a vitamin B12-deficient breast-fed infant of a strict vegetarian. *N Engl J Med.* 1978;299:317–323
11. Zmora E, Gorodischer R, Bar-Ziu J. Multiple nutritional deficiencies in infants from a strict vegetarian community. *Am J Dis Child.* 1979;133:141–144
12. Shull MW, Valadian I, Reed RB, et al. Seasonal variations in preschool vegetarian children's growth velocities. *Am J Clin Nutr.* 1978;31:1–2
13. Dwyer JT, Andrew EM, Valadian I, Reed RB. Size, obesity, and leanness in vegetarian preschool children. *J Am Diet Assoc.* 1980;7:434–439
14. Fulton JR, Huttom CW, Stitt RK. Preschool vegetarian children. *J Am Diet Assoc.* 1980;76:360–365
15. Shinwell ED, Gorodischer R. Totally vegetarian diets and infant nutrition. *Pediatrics.* 1982;70:582–586
16. Dwyer JT, Andrew EM, Berkey C, et al. Growth in "new" vegetarian preschool children using the Jenss-Bayley curve fitting technique. *Am J Clin Nutr.* 1983;37:815–826
17. Shull MW, Reed RB, Valadian I, Palombo R, Thorne H, Dwyer JT. Velocities of growth in vegetarian preschool children. *Pediatrics.* 1977;60:410–417
18. Sanders TAB, Purves R. An anthropometric and dietary assessment of the nutritional status of vegan preschool children. *J Human Nutr.* 1981;35:349–357
19. van Staveren WA, Dhuyvetter JH, Bons A, et al. Food consumption and height/weight status of Dutch preschool children on alternative diets. *J Am Diet Assoc.* 1985;85:1579–1584
20. Dwyer JT, Dietz NH, Andrews EM, Suskind RM. Nutritional status of vegetarian children. *Am J Clin Nutr.* 1982;35:204–216
21. Faber M, Gouws E, Benade AJ, Labadarios D. Anthropometric measurements, dietary intake and biochemical data of South African lacto-ovovegetarians. *S Afr Med J.* 1986;69:733–738
22. Brown AT, Bergan JG. The dietary status of "new" vegetarians. *J Am Diet Assoc.* 1975;67:455–459
23. Dwyer JT, Dietz WH, Hass G, Suskind R. Risk of nutritional rickets among vegetarian children. *Am J Dis Child.* 1979;133:134–140
24. Harland BF, Peterson M. Nutritional status of lacto-ovo-vegetarian Trappist monks. *Research.* 1978;72:259–264
25. Immerman AM. Vitamin B_{12} status on a vegetarian diet. *World Rev Nutr Diet.* 1981;37:38–54
26. Young YR, Puig M, Queiroz E, et al. Evaluation of the protein quality of an isolated soy protein in young men: relative nutrition requirements and effect of methionine supplementation. *Am J Clin Nutr.* 1984;39:16–24
27. Helman AD, Darnton-Hill I. Vitamin and iron status in new vegetarians. *Am J Clin Nutr.* 1987;45:785–789
28. Christoffel K. A pediatric perspective on vegetarian nutrition. *Clin Pediatr.* 1981;20:632–643
29. Krey SH. Alternative dietary lifestyles. *Prim Care.* 1982;9:595–603
30. MacLean WC, Graham GG. Vegetarianism in children. *Am J Dis Child.* 1980;134:513–519
31. Register UD, Sonnenberg IM. The vegetarian diet. *J Am Diet Assoc.* 1973;62:253–261
32. Vyhmeister IB, Register UD, Sonnenberg IM. Safe vegetarian diets for children. *Pediatr Clin North Am.* 1977;24:203–210
33. Levin N, Rattan J, Gilat T. Mineral intake and blood levels in vegetarians. *Isr J Med Sci.* 1986;22:105–108
34. Mueller WH. Parent-child correlations for stature and weight among school aged children: a review of 24 studies. *Hum Biol.* 1976;48:379–397
35. Himes JH, Roche AF, Thissen D, Moore WM. Parent-specific adjustments for evaluation of recumbent length and stature of children. *Pediatrics.* 1985;75:304–313
36. *National Center for Health Statistics Growth Curves for Children, Birth–18 Years, United States.* Hyattsville, MD: US Dept of Health, Education, and Welfare publication (PHS)78-1650; November 1977
37. Hamill PVV, Drizd TA, Johnson CL, Reed RB, Roche AF, Moore WM. Physical growth: National Center for Health Statistics percentiles. *Am J Clin Nutr.* 1979;32:607–629
38. Waterlow JC, Buzina R, Keller W, Lane JM, Nichaman MZ, Tanner JM. The presentation and use of height and weight data for comparing the nutritional status of groups of children under the age of 10 years. *Bull WHO.* 1977;55:489–498
39. Delgado H, Fajardo LF, Klein R, et al. Use and interpretation of anthropometric indicators of nutritional status. *Bull WHO.* 1986;64:929–941
40. *National Center for Health Statistics. Vital Statistics of the United States 1976; Volume 1: Natality.* Hyattsville, MD: US Dept of Health and Human Services; 1980
41. Carter JP, Furman T, Hutcheson HR. Preeclampsia and reproductive performance in a community of vegans. *South Med J.* 1987;80:692–697
42. Neumann G, Alpaugh M. Birth weight doubling time: a fresh look. *Pediatrics.* 1976;57:469–473
43. Taitz LS. Infantile overnutrition among artificially fed infants in the Sheffield region. *Br Med J.* 1971;1:315–316
44. Dibley MH, Goldsby JB, Staeling N, Trowbridge FL. Development of normalized curves for the international growth reference: historical and technical considerations. *Am J Clin Nutr.* 1987;46:736–748
45. Dibley MH, Staeling N, Nieburg P, Trowbridge FL. Interpretation of Z-Score anthropometric indicators derived from the international growth reference. *Am J Clin Nutr.* 1987;46:749–762

Growth of Vegetarian Children: The Farm Study

Joan M. O'Connell, Michael J. Dibley, Janet Sierra, Barbara Wallace, James S. Marks and Ray Yip

Pediatrics 1989;84;475

Growth of Vegetarian Children: The Farm Study

Joan M. O'Connell, Michael J. Dibley, Janet Sierra, Barbara Wallace, James S. Marks and Ray Yip

Pediatrics 1989;84;475