Protein intake of well-nourished children and adolescents

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ABSTRACT A number of dietary studies were made in order to learn the protein intake of children who were considered as being healthy and well-nourished while eating their customary diets. Observations of 480 boys and girls 1 to 20 years of age are reported. Individual diets for 1 to 2 weeks were weighed, and all foods were analyzed for nitrogen content. The findings indicate that protein intake varied with the rate of growth, age, and body size. The mean total intake of boys at any age or size was higher than that of girls of the same age or size. The total protein intake increased with age throughout the period of growth and with growth in size as measured by height, weight, and surface area. The highest correlation appeared between total intake of girls through puberty and between that of both boys and girls and height throughout growth. The lowest was between total intake and age. There was a high negative correlation between protein intake per kilogram body weight and age. The total intakes referred to age were comparable to the earlier findings by Eppright and Burke but lower than some more recent reports and higher than the 1968 Recommended Daily Dietary Allowances. Am. J. Clin. Nutr. 26: 1303–1310, 1973.

A series of studies of the nutritional needs and food consumption of boys and girls was carried out under the supervision of the late Dr. Lydia J. Roberts at the University of Chicago over a period of years. The energy intake of the well-nourished children and adolescents observed from 1927 to 1943 were reported earlier (1). In this paper, the amount of protein which 480 of the same children were eating is reported.

Some subjects lived in well-run institutions, others in their own homes. They were observed under their ordinary living conditions and eating their accustomed food, in amounts they chose within the limits of the meals provided. The diets were varied, the amounts generous. Generally meat, fish, or fowl was served once each day; some protein-rich dish, i.e., eggs, cheese, beans, or flesh, was served at a second meal. A pint or more of milk each day was provided for small children, a quart or more for older ones. Vegetables, fruit and cereals were served each day. The length of the studies varied from 7 to 18 days. All foods eaten at the table or between meals by each child were weighed. The oxycalorimeter was used to determine energy values; nitrogen was determined by the standard Kjeldahl method. Details of the methods used to ascertain the nutritive values of the diets and to judge the nutritional condition of each subject are given in the previous publication (1). The only data used were those obtained from observation of the children judged to be in good to excellent physical and nutritional condition.

Intake of protein by children during growth

Protein needs of children are often expressed as total grams per day in reference to age. As a somewhat closer relationship was found between the total energy intake of the well-nourished Chicago area children when referred to measures of body size (weight, height, and surface area) than to age, it seemed of interest to evaluate the data of protein intakes in the same fashion. Only data in which the protein content of the food was ascertained by analysis for nitrogen were used.

1 Present address of Dr. Bernice Wait Wood is: 525 W. Arlington Pl. Apt. 152, Chicago, Illinois 60614. The total data, including those from her own study of adolescent girls, were analyzed and the manuscript was prepared by the author. A large percentage of the data was collected by the late Dr. Ruth Blair or under her supervision.
Findings when total protein intake was referred to age

The differences between the total daily protein intakes of the Chicago boys and girls after infancy was striking, as indicated by the means in Table 1 and the curves of the means and the scatter of individual intakes in Fig. 1A and 1B. A high correlation existed between the total intake of boys and age. The mean rose from 40.6 g at 1 year to 106.7 g at 14 years and 117.8 g for two 20-year-olds. The rate of the rise increased between 10 and 14 years as was found for energy intake (1) and corresponded to the period when the most rapid growth usually occurs in boys. The curve of the mean daily protein intake of girls rose at a less rapid rate but steadily from 39.6 at 1 year to 70 g at 12 years, and after 13 years declined slowly to 60 g at 18 years.

![Table 1](https://academic.oup.com/ajcn/article-abstract/26/12/1303/4695213)

**Findings when total protein intake was referred to measures of body size**

When total protein intakes of these well-nourished Chicago children were referred to measures of body size, there were differences in the intake of the sexes (Fig. 2). At every weight and height bracket and above 0.6 m² of surface area, mean intakes of boys were greater than those of girls of the same size. The differences in the protein intake of the smaller boys and girls was not marked but increased with growth in body size as with age.

**Weight.** When the total protein intake of boys was referred to weight, a close relationship was found from the 10- through the 50-kg brackets (43 to 108 g protein). The mean intakes then increased more slowly to 122 g at 80 kg (Fig. 2A). The closer relationship between protein intake and weight was more apparent for girls. Whereas the increase of the means was not as great as that for the boys, it was higher than when intakes of girls were referred to age, and the scatter of individual intakes was much...
less. The mean was 39 g for the 10-kg bracket to 68.5 at 35 kg and decreased slowly after 45 kg (Fig. 2B).

**Height.** When total protein intake was referred to height, the picture was different (Fig. 2C and 2D). The curve of the mean intakes of the boys approached a straight line from 37 g/day by the shortest boys to 95 g by boys 150 cm in height, followed by a slightly greater upward trend to 121 g by boys 180 cm tall. The curve of the mean intakes by girls also approached a straight line to 150 cm height and 67.5 g protein. Then it flattened out. In each instance, the individual intakes tend to cluster about the mean up to 150 cm of height with a wide scatter among the intakes of the taller individuals, but less than when total protein was referred to either weight or age.

Young children gain much more rapidly in height than in weight (2). This was particularly noticeable in the boys of the Chicago studies. Also, the curves of growth in height show almost no increase in the rate of growth during pubescence as do the curves for gain in weight. This is reflected in the curves of the mean protein intakes when referred to weight and height.

**Surface area.** When total protein intake was referred to surface area, which is obtained by a formula using both weight and height, the curves of the means fell between those for weight and height and near the same level as the curve of the mean intakes referred to age (Fig. 2C and 2F). The curve for the mean intake per square meter by boys was smoother and the tendency of the individual intakes to cluster about the means greater, indicating a somewhat closer relationship between total protein intake of boys and their surface area than between intake and age. For girls the two curves were almost identical with little difference in the scatter of individual intakes.

Considerable variations in individual protein intakes occurred in each analysis. This is not strange because children at every age vary greatly in stature. Considering all the charts in Figs. 1 and 2, the lowest correlation was found between total protein intake and age, as was found for energy intakes (1). Judged by the relative scatter of individual intakes there is a high correlation between total protein intake and weight from infancy through pubescence, particularly in the case of girls. However, the steady increase in mean intake with height extended through adolescence, indicating increase with growth. The curves for surface area are similar to those for age but smoother with less scatter in the case of boys. All three measures of size influenced intake of protein and each undoubtedly contributed to the amount of protein intake by individuals in any size bracket.

An increased scatter of individual intake by the older, heavier, taller or larger Chicago boys and girls occurs in each chart in Figs. 1 and 2. For one small group of girls 8 to 17 years of age.
FIG. 2. Relationship between the total daily protein intake of boys (A, C, E) and girls (B, D, F) and measures of body size, i.e., weight, height, and surface area. The individual intakes and the smoothed curves of the means are given.

age, records were obtained to approximate their stage of development. The mean protein intakes of these girls rose as the number of "little" girls decreased to a peak at 13 years when all were growing rapidly and declined as the number of physically mature girls increased. Differences in their stage of physiological development at any age during adolescence may help explain the
great variations in individual protein intakes by both boys and girls after 12 or 13 years and the scatter of intakes by the heavier, taller and larger adolescents.

Findings compared with those from other studies

A number of studies have been reported of large numbers of children in which the nutritive value of the diets was calculated. Widdowson in 1947 (3) reported her study of over 900 healthy boys and girls 1 through 18 years of age living in the British Isles. Food intakes of each child for 1 week were weighed. In 1954, Epplight and her co-workers (4) reported their study of 1,188 Iowa schoolchildren. Records were kept of the measured amounts of food eaten by each child for 7 days. In 1958, Burke and her colleagues (5) in Boston reported the protein intakes of 67 boys and 67 girls who came to her clinic for routine physical checkups over a period of 17 years. From 2,707 dietary histories, the mean protein intakes of boys and girls from 1 to 18 years were estimated. As part of the nationwide food consumption survey made in 1965 by the USDA (6), information was obtained about the food eaten by family members both at home and away from home during the day preceding the interview, using the recall method. In the families surveyed, there were 8,135 children and adolescents under 20 years of age.

In Figs. 3A and 3B, the curves of the mean protein intakes by boys and girls in the Chicago studies are compared with the findings in the above studies and with the amounts of protein proposed in the 1968 Recommended Daily Dietary Allowances (7). The mean intakes of protein by boys and girls in each study were well above the 1968 allowances. In fact, the protein intakes reported for boys in the United States exceeded even the 1958 Recommended Allowances for protein, which were notably higher for each age level than those of 1968. The daily protein intakes of British boys closely approximate the 1958 allowances. Those for girls in the various studies were generally similar to the 1958 Recommended Daily Allowances except for those in the 1965 USDA survey, in which protein intakes higher than the 1958 allowances were reported.

In the Chicago studies, the mean intakes were consistently higher when protein values were calculated than when they were determined by analysis for nitrogen. This was true in studies when both methods were used. It is of interest, therefore, to note the unanticipated similarity at each age between the mean protein of the Chicago boys and those reported for Boston boys by Burke (5). In both, there was a rise in the curves during pubescence followed by a leveling off; at age 17 years, the mean intake in both was 110 g. The protein intake of Iowa school boys reported by Epplight (4) showed no marked rise during pubescence. The mean intake at 17 years was 105 g. After 4 years of age, the protein intakes of British boys (3) were lower than those of the boys in the United States, 95 g at 17 years of age. The 1965 USDA survey (6) shows

![Diagram of protein intake comparison]

FIG. 3. Comparison of the mean daily protein intake of the boys (A) and girls (B) of the Chicago studies with the findings of other observers and with the 1968 Recommended Daily Dietary Allowances for protein (NRC). From 6 to 18 years, lower allowances are indicated for lighter weight children.
high protein intakes by small children (56.3 g by 1- to 2-year olds) which increased steadily to a level slightly higher than that of the Chicago boys during adolescence (113.5 g at 15 to 18 years).

The mean protein intake of the Chicago girls is similar to those of the British girls to 13 years, but was less in the adolescent period. The intakes of girls observed by both Eppright and Burke are somewhat higher as had been anticipated because of the different methods used to obtain the protein content of the diets. In the 1965 USDA survey, the mean protein intakes reported for girls after 8 years of age increased to 80.6 g at 12 to 14 years. In each report, there is a point beyond which the mean intake was less than during the period of rapid growth. For the Iowa girls it was at 12 years; in the Chicago study, 12 to 13 years; 13 to 15 years in Burke's report; and 15 years in Widdowson's and the 1965 survey.

A "moderate" intake of protein is reported in most of the studies of healthy children. Do the high intakes of the recent investigations (6, 8) reflect the emphasis that has been put on the importance of protein, especially from animal sources, or is it because foods from these sources are flavorful, available, and prestige foods? Is there not a danger that fruits, vegetables, and even milk will be crowded out with the result that the diet will be inadequate in other respects, although high in animal protein?

Findings when protein intake per unit of body size was referred to age

Earlier, it had been assumed that protein intake per unit of body weight would be a more accurate index of need than total intake, for protein is a constituent of body tissue. As total protein is also more closely related to height and to surface area than to age, might the intakes per centimeter and per square meter also be good indices? The results of the analyses are given in Fig. 4A through 4F.

Protein intake as grams per kilogram per day is the method most often used to express protein requirements. The summary of protein needs of children by Irwin and Hegsted (9) indicate that the results of studies lack agree-

FIG. 4. Daily protein intakes of boys (A, C, E) and girls (B, D, F) per unit of measure of body size, i.e., weight, height, and surface area, at each age. Individual intakes and smoothed curves of the means are given.
ment. Protein requirements for growing children have been estimated to be 1 to 4 g/kg per day, with 4 g being considered a generous allowance. The lesser amounts may be sufficient for growth providing other provisions for energy are adequate.

The mean protein intakes per unit of weight found in the Chicago studies for children 1 to 4 years of age were 3.0 to 2.7 g/kg; for boys 18 to 20 years old, 1.7 g; and for girls at 16 and 17 years, 1.2 g (Table 1). The scatter of individual intakes per kilogram by young children was wide but it was between 2 and 4 g/kg after 18 months (Fig. 4A and 4B). Individual intakes of most older boys fell between 1.5 and 2.5 g; those of older girls between 1.0 and 2.0 g/kg. The differences found in the total protein intakes of teenagers had disappeared.

These intakes were well above the minimum requirement estimated by Hegsted (10) in 1957. The intakes of Chicago girls followed closely the per kilogram intakes reported by Widdowson (3), by Eppright (4), and the protein allowances proposed by the Ministry of Public Health of London (11) in 1964. The intakes of the Chicago preschool boys were comparable to those of the English boys and the proposed British allowances per kilogram, but were somewhat higher than either after 6 years.

The protein intakes per centimeter of height by children and adolescents of the Chicago studies and the curve of the means at each age are shown in Fig. 4C and 4D. At 1 year, the protein intake of boys was 0.44 g/cm; somewhat higher, 0.55 g, at 10 years; approximately 0.66 g from 14 to 20 years. The scatter of intakes was wide. The mean protein intake per centimeter per day by girls varied little. At 2 and 13 years, it was 0.45 g/cm and 0.37 g at 17 years. After 3 years, the individual intakes fell between 0.30 and 0.55 g/cm per day. The protein intake per centimeter by a number of healthy preschool children in their own homes were reported by McKay and her co-workers (12–14) as were those in Macy’s (15) metabolism studies of children. In both studies, the intakes per centimeter were similar to those of the Chicago children of the same ages.

The mean protein intakes per square meter of body surface by the Chicago boys were almost constant at 70 g from 2 to 14 years, as were the mean energy intakes per square meter through the same ages (1). At 20 years, the mean was 63 g. The scatter of the individual intakes was quite wide (Fig. 4E). The mean intake of protein per square meter by girls was not constant but dropped steadily from 73.1 g/m² at 1 year to 60.5 g at 16 years (Fig. 4F). The scatter of intakes was wider than when referred to either weight or height. The intakes reported by Macy (15) for protein intakes per square meter by both boys and girls were higher than the means but within the range of intakes found in the Chicago studies.

The mean intakes of protein per unit of surface area by boys were constant until near the end of the period of pubescence, whereas those of girls declined steadily from 1 to 18 years. The mean intake of protein per unit of height by girls remained constant during the period of growth and individual intakes tended to cluster close to the mean; that for boys increased during the comparable period. The intakes per kilogram decreased consistently for both boys and girls. After 5 years, the tendency of the intakes to cluster about the means was greater than in any other analysis, particularly in the adolescent years.

Summary

Protein intakes of 480 well-nourished children and adolescents in the Chicago area studied at the University of Chicago are reported. The subjects were observed under their regular living conditions, either in their own homes or in well-run institutional homes, eating their customary diets. The protein content of the diets were determined by analysis for nitrogen.

The Chicago studies show a level of protein intake on which children from infancy to 20 years of age were judged to be healthy and well-nourished. The findings indicate variations in protein intake with rate of growth, age, and body size and between boys and girls.

The total protein intake was higher for boys than for girls at every age. At each weight, height, or surface area bracket, the mean protein intake was higher for boys than girls of the same size. Total protein intakes increased with age throughout the period of growth; and with growth in size as measured by weight, height, and surface area. The mean protein intakes per kilogram decreased with age. In general, a close relationship was found between total protein...
intake and measures of body size; the highest correlation appears between the total intake of girls and weight from infancy through pubescence and between total intake of both boys and girls and height throughout growth; the lowest was between total protein intake and age. There was a high negative correlation between protein intake per kilogram of body weight and age.

It would appear that weight and height are dominant influences on protein intake and that surface area combines the effects of the two. Age is a measure of growth in time and reflects changes in weight and height as the body grows in size.

References