Urinary Excretion of Creatinine of Children under Different Nutritional Conditions

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IN 1908, Shaffer[1] demonstrated that the daily excretion of creatinine in adult man is remarkably constant over long periods of time, even under the most varied circumstances. Because the quantity excreted is little affected by diet, exercise or volume of urine, the daily creatinine excretion is used to determine the completeness of twenty-four hour urine collections.

Since creatinine excretion is determined principally by lean body mass,[1-3] the number of milligrams excreted in twenty-four hours per kilogram of body weight, the "creatinine coefficient," has long been used as an index of the relative amount of muscle in an individual. The daily creatinine excretion of obese persons is low in relation to their ideal weight.[5] When overweight is reduced by dietary means, the absolute excretion of creatinine does not change. On the other hand, persons with below normal weights tend to have abnormally low "creatinine coefficients" which reflect subnormal development of muscle mass.

Recently, Stearns et al.[6] have summarized the results of twenty-five years of investigation in a "creatinine coefficient" curve for well nourished children one to ten years of age in Iowa. Both Talbot[7] and Daniels and Hejinian[8] have used the "creatinine coefficient" as an index of nutritional status in children although the latter prefer to relate creatinine excretion to height for this purpose.

We have adopted the expression *milligrams of urinary creatinine per centimeter of body height;* since it is not affected by the amount of adipose tissue, it is a better indicator of the relative development of lean body mass than the commonly employed "creatinine coefficient." The present study presents preliminary observations on the excretion of creatinine per centimeter of height in children with nutritional status varying from excellent to acute kwashiorkor.

MATERIAL

Group A

Urban Upper Socioeconomic Group. Fifteen students of a private school in Guatemala City, who ranged in age from six years five months to eight years seven months, were studied together with eight children, who ranged in age from two years two months to five years five months, from families of local professionals.

Group B

Rural Lower Socioeconomic Group. Eight children living in the rural highland village of Santa María Cauqué were studied; they ranged in age from three to six years.

Group C

Patients with Kwashiorkor. This group included twenty-two patients hospitalized with acute kwashiorkor in the metabolic unit of INCAP. The urinary excretion of creatinine was measured in nine of these children during the first days of hospitalization and again six to eighteen months after the child was considered to be clinically recovered. Only initial values were obtained in nine cases and values only after recovery in the remaining four.

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TABLE 1
Daily Intake of Preschool Children as Percentage of INCAP Recommended Allowances
(Eight Cases per Group)

Nutrient	INCAP Recommendation	Socioeconomic Level			
		Urban Upper		Rural Lower	
		%	Range	%	Range
Calories	1,425	133	112–156	73	36–111
Total protein (gm.)	47.5	145	106–171	62	26–97
Animal protein (gm.)	15.8	332	204–422	50	0–139
Riboflavin (mg.)	1.15	268	184–364	37	12–55
Niacin (mg.)	7.12	146	123–184	77	48–105
Thiamin (mg.)	0.75	176	128–318	86	44–126
Ascorbic acid (mg.)	46.00	240	144–524	43	16–110
Vitamin A (I.U.)	2,375	413	116–1,150	47	3–121

METHODS

The urine was collected during twenty-four hours, except in the fifteen students of the private school, in whom only three-hour collections were made. When twenty-four-hour collections were not made, the twenty-four-hour excretion of creatinine was obtained by calculation. High correlations have been found in our laboratory between "muscularity" and twenty-four-hour urinary creatinine excretion values per centimeter of body height calculated from three-hour specimens from twelve boys and fifteen girls. The former was obtained from arm circumference and skinfold data using the formula of Brozek.[9] The correlation coefficients were 0.96 for boys ($P < 0.001$) and 0.85 for girls ($P < 0.05$). Further evidence of the feasibility of using short collection periods has been obtained from a study in twelve men and seven women in whom twenty-four-hour excretions calculated from three-hour collections (men, 1,644 mg.; women, 962 mg.) were not significantly different from those in twenty-four-hour specimens (men, 1,627 mg.; women, 964 mg.).

In the patients with kwashiorkor temporary retention of creatinine, probably of renal origin, was observed initially. This impairment disappears during the first few days of treatment with a resulting sudden rise in urinary creatinine followed by a decrease.[10] The sudden initial rise could not be due to a gain in muscle tissue since it is not conceivable that protein mass could increase so rapidly. We have called this lower more stable level the "initial" excretion of creatinine.

Toluene was used as a preservative, and the samples stored at minus 20°C. until they could be analyzed. The creatinine determinations were made by the method of Clark and Thompson.[11] The heights of all the children were obtained at the time of collection. In eight children in each of groups A and B, the food intake was estimated by means of personal interviews with the mothers.*

RESULTS

Dietary Characteristics

Table 1 presents the estimates of the intake of nutrients expressed as percentages of INCAP's dietary recommendations for children of the average age of the group studied.[12] These differ from those of National Research Council (N.R.C.) only in lower levels for calcium and vitamin C. The contrast between the relatively low intake of the rural group and the relatively excessive consumption of many nutrients of the children of the upper socioeconomic group should be noted.

The dietary intake of the children with kwashiorkor immediately before hospitalization is extremely variable and can only be

* The collaboration of Miss Marina Flores, Section Chief of Dietary Surveys, and Berta García and Zoila Flores, is appreciated.

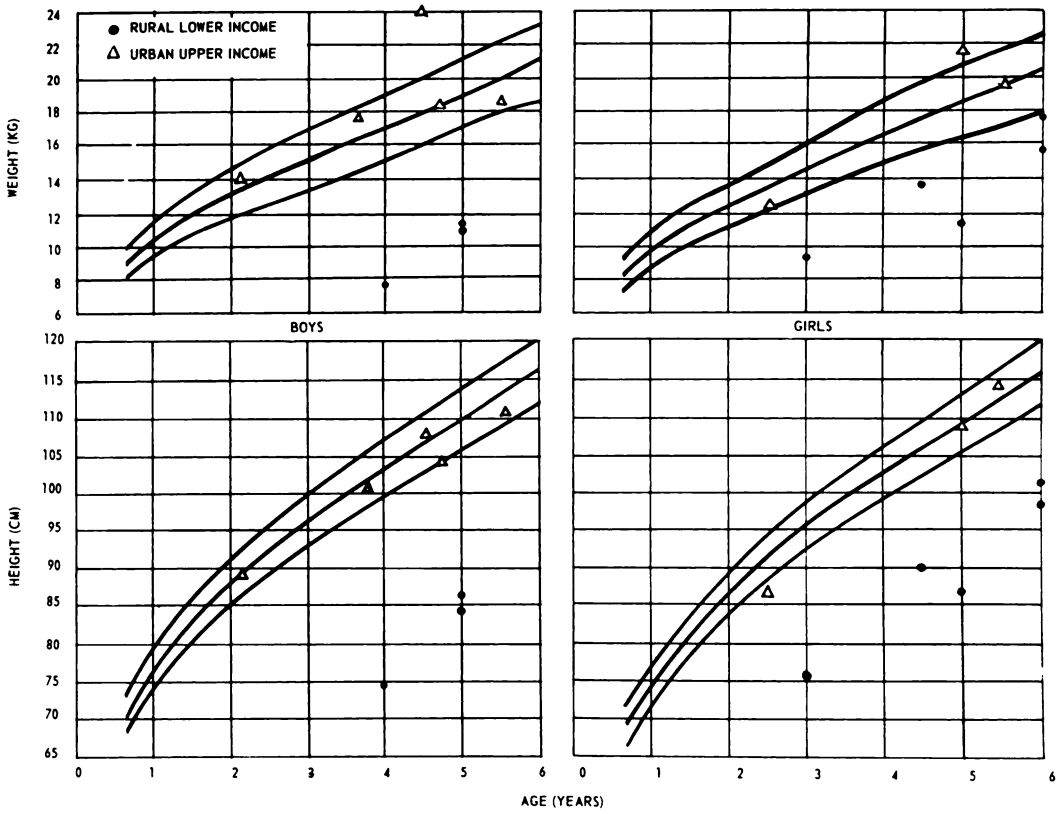

FIG. 1. Body heights and weights of preschool children of two different socioeconomic groups in Guatemala. In this figure and in Figure 2, for comparison purposes, INCAP standards for height and weight for Central America are reproduced in solid lines. The solid middle line represents the median for weight and the mean for height. The upper and lower solid lines represent the 84th and 16th percentile for weight and plus-minus 1 standard deviation for height.

estimated approximately from the history given by the mother upon the child's admission to the hospital. However, these children's diets are even poorer than those ordinarily consumed by children of the socioeconomic group from which they come. Furthermore, due to anorexia and erroneous dietary practices, the protein intake is restricted even more when the first signs of the disease become manifest.[13]

Although a direct intake of food was not investigated in the school children of the urban area, a previous study of mothers of children belonging to this group revealed that their diets contained adequate amounts of all essential nutrients.

Physical Measurements

Figures 1 and 2 confirm that children of the lower rural socioeconomic group and the patients hospitalized with kwashiorkor are markedly reduced in height and weight compared with those of high socioeconomic group.

Biochemical Measurements

In Figure 3 are illustrated the creatinine excretions, in milligrams per centimeter of height, of the different groups of children studied. The average values and their standard deviations found by Stearns[15] in adequately nourished North American children, have been included for the purpose of comparison. Seven individual values for infants from four to seven months of age, given by Daniels and Hejinian,[8] have been included. The values found for adequately nourished children in the present study generally agree with those in the papers cited.

TABLE II
Urinary Creatinine Excretion per Centimeter of Body Height in Children with Kwashiorkor

Subject	Initial		Recovered	
	Age	Creatinine (mg./cm./24 hr.)	Age	Creatinine (mg./cm./24 hr.)
PC-67	1 yr. 3 mo.	0.8	1 yr. 9 mo.	1.2
PC-82	1 yr. 4 mo.	1.0	3 yr.	1.8
PC-66	1 yr. 7 mo.	1.0	2 yr. 7 mo.	1.3
PC-83	1 yr. 10 mo.	0.9	2 yr. 7 mo.	1.6
PC-98	1 yr. 11 mo.	1.1	2 yr. 7 mo.	1.5
PC-86	2 yr. 8 mo.	1.1	3 yr. 7 mo.	2.0
PC-95	2 yr. 9 mo.	1.1	3 yr. 3 mo.	2.1
PC-102	4 yr. 9 mo.	2.0	5 yr. 3 mo.	2.5
PC-101	5 yr. 2 mo.	1.4	5 yr. 9 mo.	2.2

The children of the rural lower socioeconomic group excreted much smaller quantities of creatinine. Although the group of children with kwashiorkor were in general younger, their excretion fell on the line projected from data obtained from the rural lower socioeconomic group.

The levels of excretion in the children recovered from kwashiorkor were considerably higher. These increases with recovery are more clearly illustrated in Table II which lists those cases in which the determination was made during both the acute phase and several months after clinical recovery. In none of these children did creatinine excretion reach normal values even though they received good diets for periods ranging up to eighteen months.

COMMENTS

The amount of creatinine excreted by an individual is recognized as a good estimate of the relative amount of skeletal muscle. Exceptions to this are found under certain pathologic conditions, such as renal diseases and excessive muscle wastage, which are easy to recognize clinically and uncommon. In their work on the protein requirements of children one to ten years of age, Stearns et al.[6] suggest that the protein intake which permits the formation of an amount of muscle characteristic for a specific age group, should be considered the protein requirement for that age.

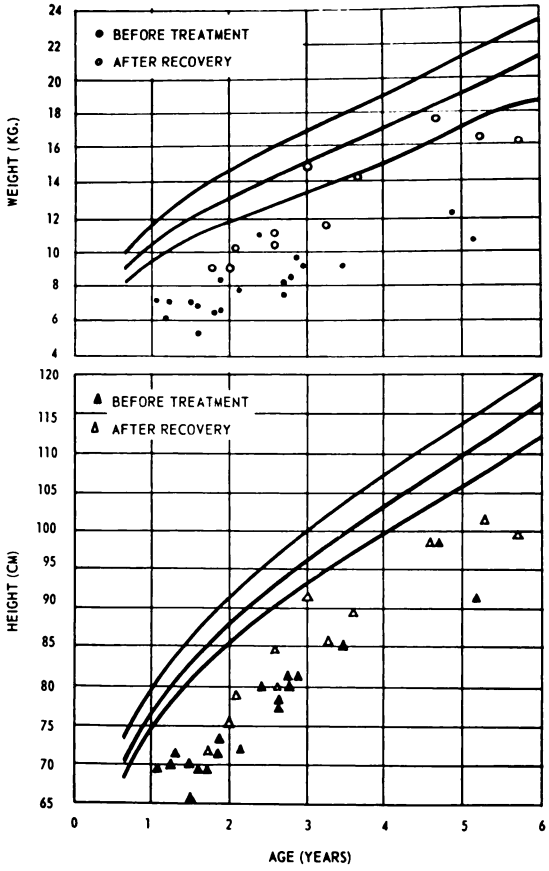

FIG. 2. Body heights and weights of children with acute kwashiorkor and after clinical recovery.

It is known that considerable skeletal muscle may be sacrificed during periods of protein deprivation to prevent the loss of protein from more important tissues. It would seem, therefore, that the protein requirements of tissues of high biological priority have been satisfied if the amount of skeletal muscle has been well maintained.

Our finding that the figures for creatinine excretion per centimeter of height in adequately nourished Guatemalan children coincide with those found by Stearns in North American children, indicates that the relative amount of muscle is the same in both groups. On the other hand, the excretion values for children of the rural lower socioeconomic group, three to six years of age, closely approach the values given by Daniels and Hejin-

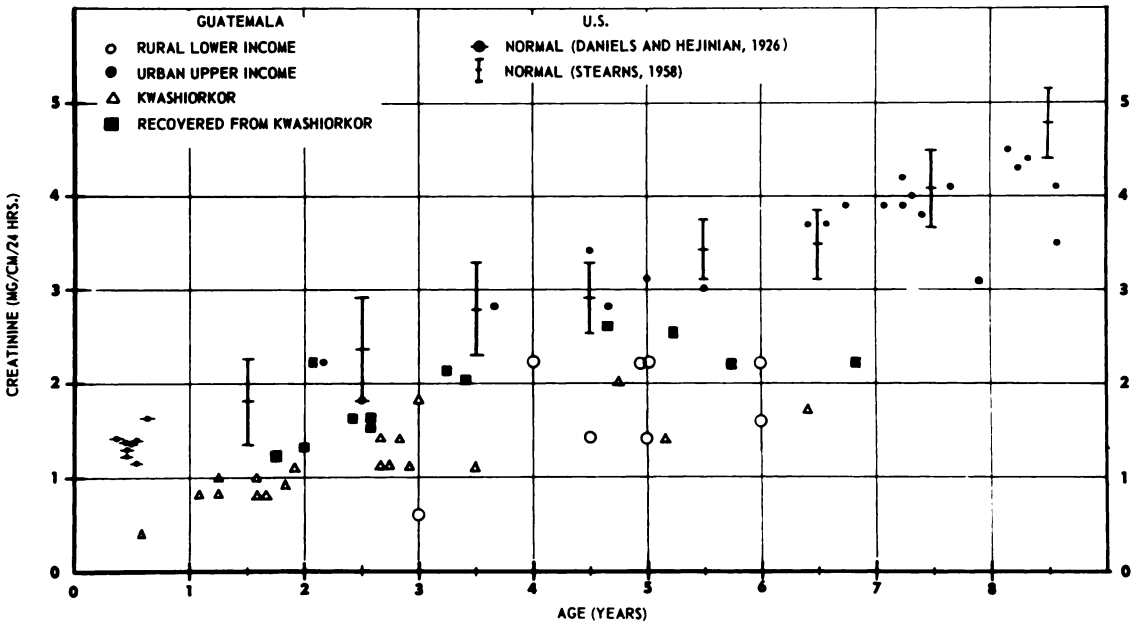

FIG. 3. Urinary excretion of creatinine in relation to body height in children of different nutritional and socioeconomic status.

ian for children four to seven months of age.[8] These values are also similar to those found in patients with kwashiorkor upon admission to the hospital. Thus, apparently healthy preschool children belonging to the economical and nutritionally underprivileged groups in Guatemala do not seem to differ radically from those with kwashiorkor as far as the magnitude of the protein depletion is concerned. The acute picture of kwashiorkor may be due to superimposed factors acting on undernourished children who are, in terms of creatinine excretion at least, ambulatory cases of latent kwashiorkor.

Although the children with kwashiorkor markedly increased their ratio of creatinine: height during recovery, reflecting a rapid muscular repletion, the majority did not reach the levels found in adequately nourished children of the same age, even after six to eighteen months of treatment. This suggests that the retardation in development resulting from the chronic severe protein deficiency suffered by these children is not readily overcome.

SUMMARY

The twenty-four–hour urinary excretion of creatinine per centimeter of body height was studied in three groups of children in Guatemala. Twenty-three came from an urban upper socioeconomic group and were adequately nourished; eight were from a rural lower socioeconomic group and twenty-two were patients with kwashiorkor.

The data from the adequately nourished children coincided with those for healthy North American children, indicating their relative muscle mass to be similar. The children from the rural group and those with kwashiorkor excreted much less creatinine per centimeter of body height. The results indicate that in Guatemala, economically and nutritionally underprivileged children without overt malnutrition do not differ radically in the magnitude of protein depletion, as indicated by creatinine excretion, from those with kwashiorkor. With recovery from kwashiorkor, a marked increase was observed in the creatinine excretion of the patients with kwashiorkor, but in the majority levels normal for their age were not reached even after six to eighteen months of treatment.

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