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9. ABSTRACT
A large-scale field study in villages in northern Thailand measured the health benefits derived from the fortification of rice with lysine, threonine, thiamin, riboflavin, vitamin A and iron. Twenty-nine villages with a total population of 13,500 were divided into five test groups: (1) raw control, no intervention; (2) placebo control, rice fortification plus day-care centers for preschool children; (3) rice, vitamin and iron fortification plus day-care centers; (4) rice, vitamin, iron, and amino acid fortification plus day-care centers; (5) rice fortification, no day-care centers. The means of rice fortification and dispensing and the day-care centers are described. The document also gives information on implementing the study, collecting data on population, mortality, morbidity and birth weight, and baseline data on both village preschool children and middle-class Bangkok preschool children. The study showed that the village children are retarded in growth and development when compared to the Bangkok children. Data obtained from an institutionalized population of preschool children in Bangkok support the hypothesis that marked catch-up growth may occur in undersized Thai preschool children supplied with a comprehensive health program which includes good nutrition.

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Amino acid fortification of rice studies in Thailand. I. Background and baseline data[1, 2]

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ABSTRACT This paper describes the organization and methods being used in a large-scale field study in villages of northern Thailand designed to measure the health benefits to be derived from the fortification of rice with lysine, threonine, thiamin, riboflavin, vitamin A and iron. Data have been obtained which show that the village children are retarded in growth and development when compared to middle Bangkok children. Data obtained from an institutionalized population of preschool children in Bangkok support the hypothesis that marked catch-up growth may occur in undersized Thai preschool children supplied with a comprehensive health program including good nutrition. *Am. J. Clin. Nutr.* 28: 170–182, 1975.

It is generally recognized that for a large percentage of people, particularly those in developing nations, the quality and quantity of the proteins in their diets present an immense nutritional problem. Projections of future population growth and agricultural production make obvious the urgency of developing methods for attacking this problem, for the implications of widespread protein malnutrition of varying degrees are alarming.

For most of the people in developing countries, grains, particularly rice, corn, and wheat, provide the bulk of their protein and dietary energy sources. The proteins of these three grains are of relatively low biological value. There are a variety of ways in which the utilization of such proteins may be increased or by which the amount of protein available to people eating diets predominantly composed of grain may be increased. These methods which include the breeding of high yield and/or high protein plants, fish farming, the production of increased amounts of meat, poultry and dairy products, the development of new high protein foods or food additives and amino acid fortification have received considerable publicity in lay and technical publications. Each method for improving protein nutrition which has been suggested has its advocates who in the process of extolling the virtues of one system are quick to point out the disadvantages of all other systems. It takes little time to realize that it is unlikely that any simple method will be devised for solving the protein problems of the world and that the key to battling protein malnutrition is flexibility, the willingness to adapt and use any or multiple systems according to the conditions prevailing in any particular nation or community. Criticisms of approaches to solving protein malnutrition usually include costs, technological and logistic difficulties, alterations of culturally determined eating patterns and difficulties in gaining acceptance because of problems involving taste, texture or the appearance of the food.

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[3] Harvard School of Public Health. [4] Mahidol University. [5] Department of Health.

This is the first of a series of papers describing a large-scale field study of the fortification of rice with synthetic amino acids and other nutrients.

Rice is the major dietary staple for considerably more than a billion people. Although the protein content of rice varies with strain and agricultural practices, the average amount of protein found in rice is about 7% (1) with a net protein utilization value of about 60 (2). The two limiting amino acids in rice are lysine and threonine (3). In rat studies in this department the addition of 0.3% lysine and 0.1% L-threonine to Thai glutinous rice increased the net protein utilization of the rice protein to that of lactalbumin (4). In recent years, technological advances permitting the large-scale industrial production of amino acids and the development of artificial and natural rice carriers of nutrients including amino acids have made the possibility of rice fortification with amino acids attractive as one of the means for combating protein malnutrition.

There are those who are skeptical of health benefits to be derived from fortification programs. Such people are particularly dubious about the possible benefits which amino acid fortification might provide. Others argue that the results of animal studies and metabolic studies are compelling and that where possible, amino acid fortification programs should be started as soon as possible. They argue that as scientists, with the data already available, it is possible to make positive decisions regarding amino acid fortification without doing large-scale field studies which, if unsuccessful for any of a large number of nonnutritional reasons, would prevent the initiation of much-needed programs. With many others, we believe that the information which exists requires that amino acid fortification of primarily grain diets be seriously considered. We also recognize that resources for solving health problems in developing societies are limited and that amino acid fortification programs will be expensive. It seems reasonable that economic planners and political decision-makers will ask proponents of nutrition programs to quantify the health benefits which their programs are expected to provide so that cost-benefit analyses for their programs can be derived and compared with competing proposals.

In late 1968, we decided to explore the possibility of initiating a field study of the effects of the fortification of rice with lysine and threonine and other nutrients in a population receiving approximately 70–80% of its calories from rice. In selecting a country in which to work, a number of criteria had to be met. It had to have a segment of its population which received the bulk of its calories from rice and in which there was evidence of protein malnutrition. The availability of rice to the population could not be so limited that benefits derived from increasing protein availability would be obscured by energy deficiency. Similarly, the extent of infectious and noninfectious diseases had to be at a level which would not obviate beneficial effects of a fortification program. The people to be served had to be cooperative and their political leaders and health workers at every level had to be receptive to the program. A group of well-trained health professionals who could work on the project had to be available. Finally, a system for delivering the fortification mixture which would work in the study area was needed. All of these criteria were met in Thailand and in the later part of 1969 the Department of Nutrition at the Harvard School of Public Health and the Division of Nutrition of the Thai Department of Health initiated a 12-month pilot study of the feasibility of rice fortification in four villages in the province of Chiang Mai.

The purpose of the pilot study was to determine as far as possible the methodological problems which might occur in doing a full-field study of rice fortification in Thailand. Following the successful completion of the pilot study, a full-field study involving 29 Chiang Mai villages in the valley of the Ping River with a total population of approximately 13,500 was started in January 1971.

The villages were divided into five groups:

Group 1—raw control, no intervention provided

Group 2—placebo control, RFG-3 plus day-care centers for preschool children

Group 3—RFG-2, vitamin and iron fortification plus day-care centers

Group 4—RFG-1, vitamin, iron and amino acid fortification plus day-care centers

Group 5—RFG-1, no day-care centers

The following are descriptions of the various

components and considerations which went into the design of these studies.

Rice fortification grains (RFG)

A major deterrent to rice fortification with amino acids has been difficulty in designing an acceptable vehicle for conveying nutrients. At least for the purposes of this intervention study, we were attracted by artificial rice granules prepared by the Ajinomoto Company of Japan. These RFG are made by an extrusion process and can be designed to carry varying amounts of a variety of nutrients. A perfect RFG would look like rice, cook like rice and taste like rice, and would maintain its nutrient qualities during the cooking process. With such characteristics, the introduction of the fortification granule into the rice supply would involve a minimum of disruption in normal cooking and feeding practices and little nutrition education would be needed. The RFG, although imperfect, were judged satisfactory for the purposes of the proposed study. Three different types of RFG added to rice at a 1% level have been used in these studies. Because of laws preventing the import of rice or rice products into Thailand, the binder in the RFG has been composed of corn starch, although we have judged that a more palatable product could be made with rice flour. The RFG are shellac coated. RFG-3 is a placebo. RFG-2 contains 0.087.3% thiamin naphthalene disulfonate (equivalent to 0.05% thiamin nitrate), 0.0815% of retinol acetate, and 0.8% $FePO_4 \cdot 4H_2O$ (0.2% iron). RFG-1 contains the two vitamins plus iron plus 20% L-lysine HCl and 10% L-threonine. Studies of the bioavailability of these nutrients and losses during processing and storage have been conducted. Rice to which RFG had been added was washed in H_2O, soaked in H_2O for 6 hours and steamed for 2 hours. Chemical analysis indicated that 82% of the lysine and 76% of the thiamin remained. Approximately 50% of the vitamin A activity of the RFG was lost in the processing and storage of the RFG. The availability of the iron in RFG-1 was determined by a standard slope ratio assay in chicks (5). Compared to ferrous sulfate, the iron in the RFG was 36% available. Interestingly, ferric orthophosphate tested separately was only 11–15% available in this type of assay.

Throughout the field studies, the availability of the amino acids in different batches of RFG have been tested in rat growth studies. In these studies, diets containing, on a dry weight basis, 90.5% fortified and unfortified rice, 4% mixed salts, 4% corn oil, 1% cod liver oil, 0.3% choline chloride, and 0.2% of a complete water-soluble vitamin mixture carried on sucrose, have been fed to weanling rats for 3–4 weeks. Before being mixed with the other ingredients, the rice has been cooked by putting it in H_2O, bringing the H_2O to boil, and then cooking under low heat for 15 min by which time the rice becomes soft and the water absorbed. In a typical 3-week feeding test, the mean weight gain ± SE for 8 weanling male Charles River CD rats fed the unfortified rice diet was 38 ± 3 g, and for those fed the fortified rice diet 69 ± 6 g. In the pilot study and during the first year of the full-field study, riboflavin was not added to the RFG because of concern over the effect that coloring the RFG might have. Because of the large number of children who showed clinical signs consistent with riboflavin deficiency, the very low levels of riboflavin in the diets consumed, and the low levels of riboflavin in the urine and serum of the Thai villagers, riboflavin was added to RFG-1 and 2 in August 1972 at 0.04%. Analyses have indicated that essentially no riboflavin is lost during the manufacturing process or during storage.

RFG dispensing equipment

Approximately 90% of the rice consumed in Thai villages is milled by small village mills. The farmers bring their paddy to the mill and pay for the milling either with cash or by giving the miller the bran. In the latter case, the rice is often over milled. In either instance, the village mills crack a very high percentage of the rice grains. In the villages of this study, payment for milling has been in cash. Villages were selected with a single mill and a cooperative miller. The mills were equipped with dispensers built in Thailand and adapted from rice enrichment feeders designed at Clemson University. The RFG dispensers cost about $50 to construct and could easily be adjusted to add RFG at a 1% level to the milled rice as it streamed forth from the mill. Daily measurements of the amounts of rice milled in each mill and the amount of RFG used indicate that in the field studies conducted, RFG has been added daily

at 1.0 ± 0.03%. All dispensers have been examined at least once a week. At no time during the study has there been any trouble with the performance of the feeders. Figure 1 shows a feeder attached to a village mill.

Day-care centers for preschool children

The provision of day-care centers for preschool children in some of the villages and an evaluation of the benefits which might be derived from them were attractive in these studies for a number of reasons. The day-care centers were a visible manifestation of our intention to provide benefits to the villages. They were enthusiastically received by the villagers and were expected to help ensure their cooperation in the study. In retrospect, it is questionable whether the day-care centers have had a significant effect on the cooperation obtained, since cooperation has been generally good in villages without them. We paid about two-thirds of the $750 cost of building the day-care centers. The villagers paid the other third and did the construction work. For each day-care center, two young adult women have been trained to be day-care attendants and paid a monthly salary by us. As with any group of workers, their quality has varied, but for the most part their performance has been very good. Children attending the day-care centers have been asked to bring their own lunches. Because of the nature of the study, no food supplements have been distributed in the day-care centers in this study. Since the day-care centers provide custodial care, many parents immediately took advantage of their availability so that they could work in the fields without worrying about their preschool children. There have been two main reasons why some preschool children have not attended the centers. Some of the villages are long geographically and some houses are so far from the village day-care center that mothers do not want to go through the daily effort of bringing their children to the center and then picking them up again. In the affectionate matriarchal Thai culture, small children are very attached to their mothers and many preschoolers refused at first to attend the day-care centers. Usually, if they could be induced to spend a few days in a center, they rapidly came to like the experience

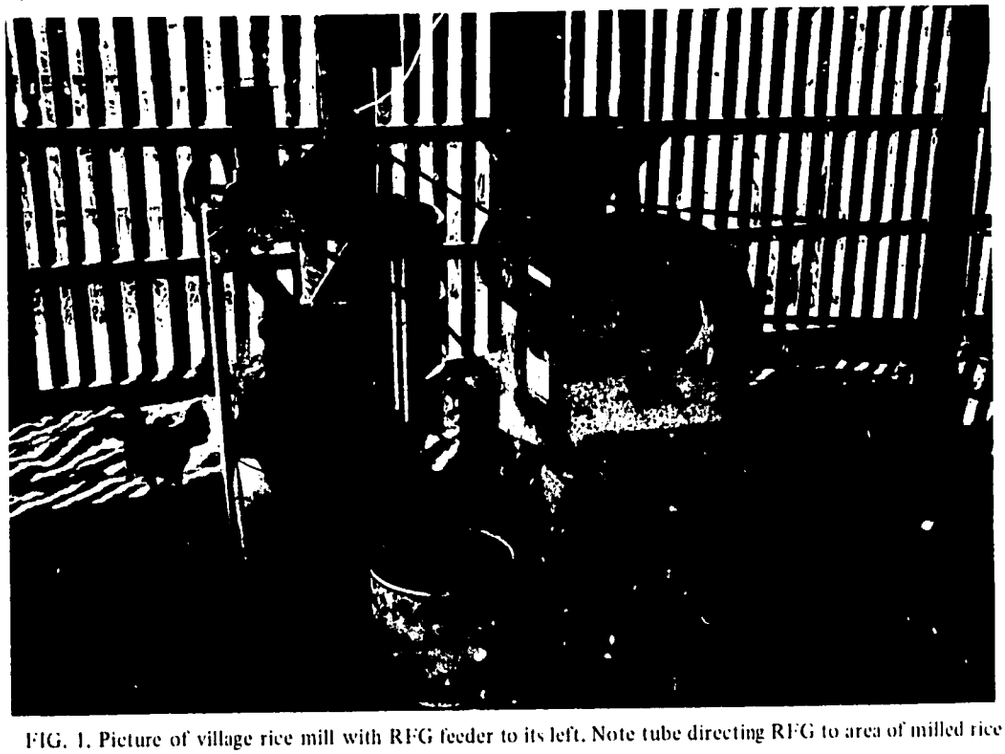

FIG. 1. Picture of village rice mill with RFG feeder to its left. Note tube directing RFG to area of milled rice flow.

and the opportunity to play with other children, and stayed without objection.

Informed consent

From the very beginning of these studies, their success has been dependent on the voluntary cooperation of the Thai villagers. At no time has there been any consideration of using any type of coercion or social pressure to obtain the participation of the village people. Thus, it was necessary to provide them with abundant correct and convincing information about the project. Villages were selected whose headmen and millers indicated enthusiasm and a desire to cooperate, after being informed about the study. In the pilot study villages, most of the information about the program was obtained by the villagers from our personnel with some coming from the headmen and millers. To our chagrin, we discovered shortly after starting the full-field study that the people were getting most of their information from the headmen and millers and little from us. Furthermore, much of the information was inaccurate or incomplete. As a result, a number of things were done. An illustrated brochure, in color, describing the purpose of the nutritional aspects of the study was prepared and distributed to all households in the villages receiving RFG. A number of mass meetings were held in each village to describe the study and answer questions, and finally we directed our personnel to live in the villages. They were asked to rotate through the villages biweekly. While there, they were asked to visit the homes and further explain the purpose and details of the study. Cooperation has been good, but has varied from village to village. At the mills, the addition of RFG has been the option of the consumer. Whether or not a child has attended the day-care centers has been a decision made solely by its parents. Use of the day-care centers has not been dependent on use of the RFG and conversely use of RFG has not been contingent on use of the day-care centers.

Personnel

These studies were initiated by a visit of members of the faculty of the Department of Nutrition at the Harvard School of Public Health to the Division of Nutrition of the Thai Department of Health in January 1969. During this visit, a considerable amount of time was spent discussing the proposed study, the reasons for doing it, and its feasibility with Thai government officials and academicians interested in nutrition, public health, and medicine. Although opinions varied widely as to what might be the best approaches to nutrition problems in southeast Asia and Thailand in particular, there was universal agreement that worthwhile information would be generated by a rice-fortification study and that it would be feasible to do such a study in Thailand. Of considerable importance, were the promises of cooperation and support which were received. Happily, the past 5 years have proved that the promises were sincere and the support provided by the various groups in the Thai Department of Health, particularly in the Chiang Mai Health Department, and by the Thai academic community has been helpful.

In addition to professional personnel needed to supervise the work and to conduct and interpret the physical, X-ray, parasitologic and other examinations, a group of people were needed on a full or part-time basis to do the day-to-day work of the study. Five holders of B.A. degrees in nutrition from the Thai School of Public Health and several drivers were hired for full-time work. As needed, laboratory technicians and dietitians from the Thai Division of Nutrition and public health nurses, sanitarians and midwives of the Chiang Mai Health Department have been made available.

The collection of data

Census data. The map presented in Fig. 2 shows that the 29 villages of the full-field study were selected in an area which extends from about 35 k north to about 65 k south of Chiang Mai. A map of each village was constructed showing the location and identifying numbers of the houses. A record of each household was made listing the names and ages of all its members. Each child from 6 months to 5 years of age was given a 7 digit identification number listing his village, family, and personal number within the family. As the study progressed, all newborn children have been added to it. As children have aged, they have not been dropped with the result that at the start of the full-field study 1,265 preschool children were examined, but currently, 3 years later, there are approximately 2,050 children in the study. The

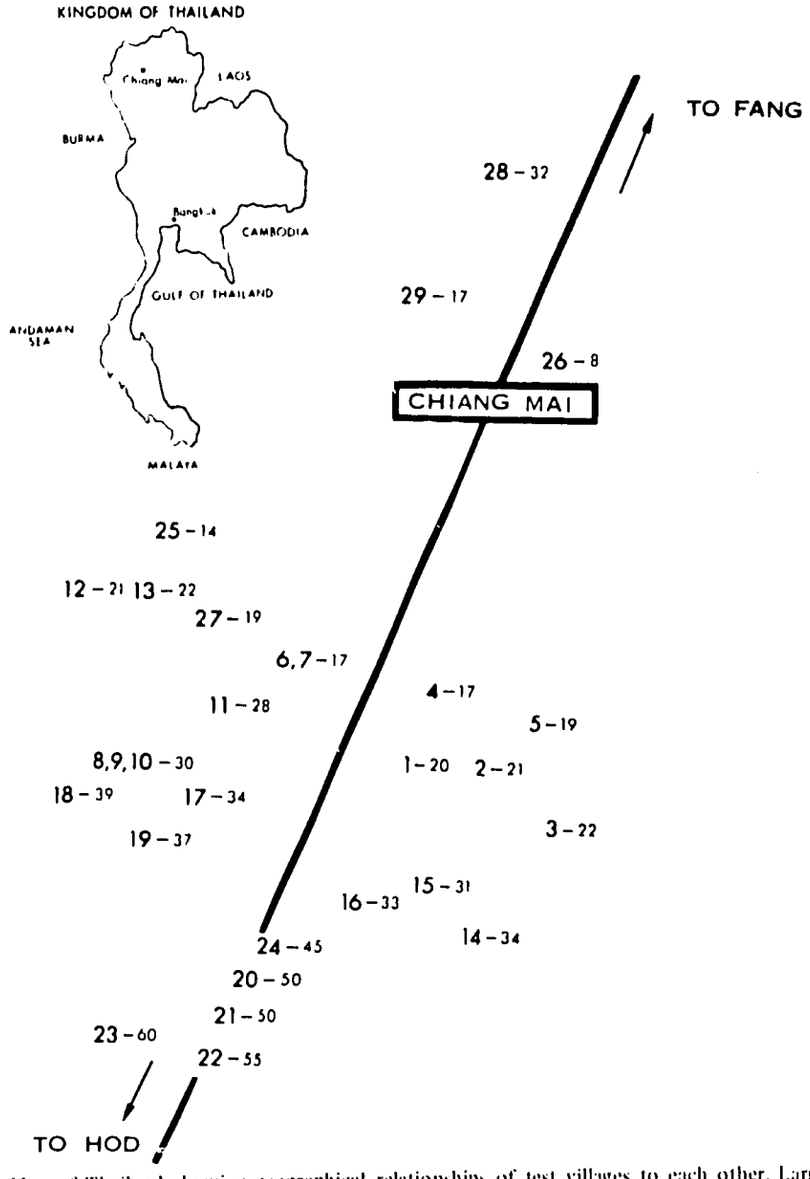

FIG. 2. Map of Thailand showing geographical relationships of test villages to each other. Large numbers identify the villages; the small numbers are the approximate distances of the villages from Chiang Mai in kilometers. Villages 14, 20, 21, 22, 24, 25 raw control. Villages 1, 3, 6, 7, 11, 26 RFG-3 + day-care centers. Villages 4, 16, 18, 19, 28 RFG-2 + day-care centers. Villages 2, 5, 8, 9, 10, 27, 29 RFG-1 + day-care centers. Villages 12, 13, 15, 17, 23 RFG-1, no day-care centers.

availability of complete census records has provided many advantages. It has been of value in getting information to the households with growing children. During examination periods, it has made immediate identification possible of children not examined, thus permitting on-the-spot visits to their houses to remind their parents that the examinations were taking place. As a result, during each study period more than 99% of the children in the study have been examined. The census data have also been of assistance in obtaining information about births, morbidity, and deaths.

Physical examinations. Two physical exami-

nations have been conducted every year one in January-February and the other in July-August. January in Chiang Mai is a period with little rain. The temperature may drop into the 40's at night but rises to 85-90 during the day. It is the period after the harvest and food shortages are minimal. July and August are monsoon months. The temperature at night is about 70 and during the day about 90. It is very humid and during heavy rains flooding may occur. Infectious diseases, particularly diarrheal and respiratory, are more prevalent than in the beginning of the year.

During both examinations, a short medical history is obtained. Reclining lengths, weights, head, arm and chest circumferences, and triceps and subscapular skinfolds are measured. The Thai children in this study all have birth certificates with their date of birth. Knowledge of birth dates has been very helpful in evaluating the anthropometric data. A physical examination directed toward signs associated with nutritional disease is done. However, other medical problems such as infectious disease or physical abnormalities are noted. Although we are aware of the effects of extraneous interventions in studies of this type, parents have been appraised of acute health problems and how to obtain medical care for their sick children. In some instances we have transported children to Chiang Mai and had them admitted to the University Hospital.

During the winter examination, hemoglobin and hematocrit determinations have been done on the mothers and the children older than 1 year. In addition, hand wrist X-rays have been obtained of the children and where possible (50–60%) fecal samples have been examined for parasites.

Figures 3, 4, and 5 show the cards on which the information collected is placed before being transferred to IBM cards.

Collection of mortality, morbidity and birth weight data. In studies of this kind, important insights can be achieved from examinations of mortality, morbidity, and birth weight data. Unfortunately, the collection of these data often presents problems. In the present study, because of the completeness of the census data and the constant communications between our field personnel and the people of the villages, it has been possible to collect mortality data.

At the start of the full-field study morbidity data were obtained during the physical examinations and from records kept at the day-care centers. It became obvious that this would not supply adequate information, particularly since the results of other studies in different parts of the world indicated that oftentimes significant effects of interventions could be found in morbidity data when anthropometric changes were not seen. Starting July 1, 1972 a system for collecting morbidity data on each child every 15 days throughout the year was initiated. The mechanics of doing this will be described in another report. The collection of morbidity data has been accompanied by two other benefits. It has improved surveillance of the use of the RFG and it has helped in obtaining the weights of newborn babies. Because only a small percent of the expectant women use the government midwives stationed in each village, it has been impossible to collect the weights of babies at birth. However, it is now possible for us to collect weights of babies during the first 15 days of life.

Chiang Mai village preschool children base line data. Baseline data were obtained in the 29 test villages during the winter and summer of 1971. The following data were derived from the winter examination. The total population of the villages was approximately 13,500. There were 1,265 children between the ages of 6 months and 5 years in the villages. All were examined. Only one failed to get a hand wrist X-ray and about 848 provided fecal samples for a parasite examination. The children came from 985 families. Bloods for hemoglobin and hematocrit determinations were obtained from 928 of the mothers of the children examined. Table 1 presents the blood data of the mothers and children examined using criteria adapted from the Interdepartmental Committee on Nutrition for National Defense (6). As can be seen from these data, more than 20% of the mothers showed nonacceptable hemoglobin and hematocrit values and similarly large numbers of the children showed not acceptable hemoglobin values. However, with the standards used, the children's hematocrit values were not as poor.

The most common clinical findings consistent with malnutrition were angular lesions observed in 2.5% and 4.2% of the children examined, respectively, in the winter and

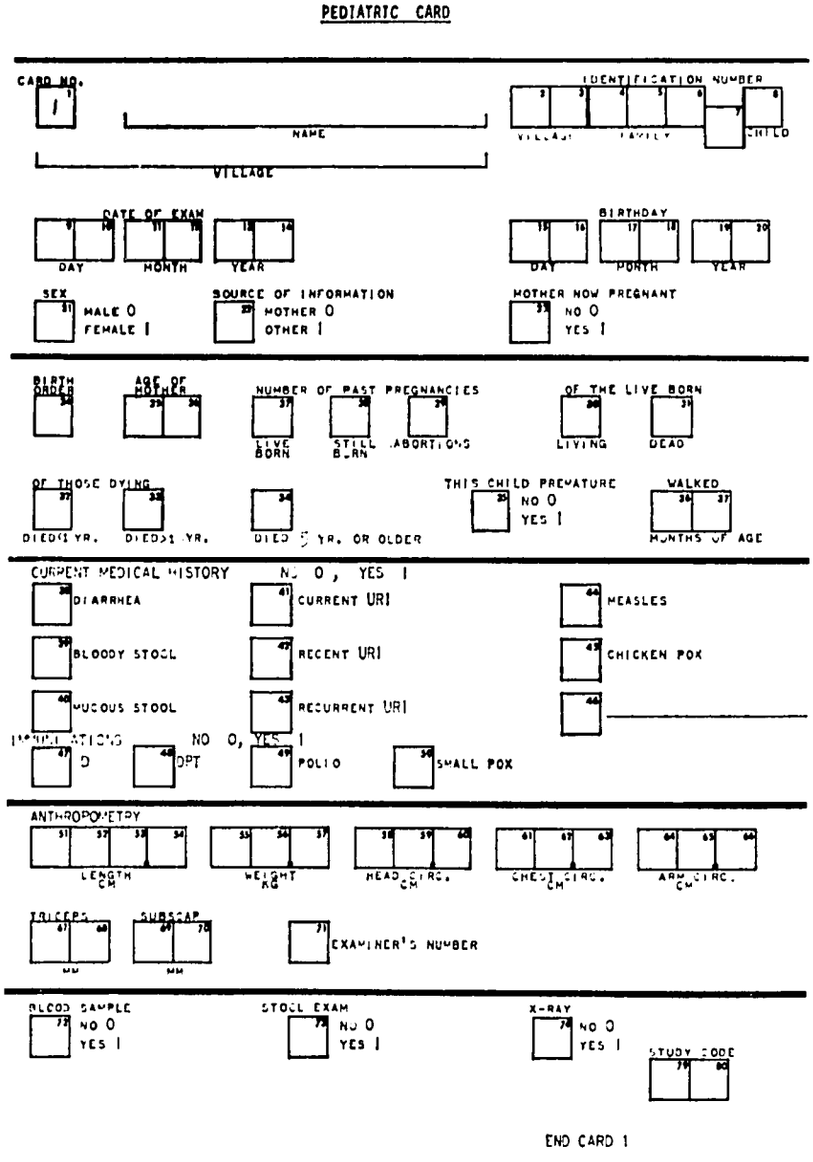

FIG. 3. Card 1 used in listing data.

summer of 1971 and filiform papillary atrophy seen in 1.5 and 3.2% of the children in the two examinations. Of the 848 fecal samples examined 232 (27%) showed evidence of hookworm infection, 92 (11%) of ascaris, 14 (2%) of taenia, and 120 (14%) of other parasites.

Considerable information was obtained about the reproductive histories of the mothers. The ages of the mothers and the percent of the total in each age category were as follows: 16–19 years of age (3.2%); 20–24 (22.1); 25–29 (18.9); 30–34 (18.9); 35–39 (19.8); over 40 (17.1). The number of living children each woman had at the time of the examination and the percent of mothers in each category were: 1 child (21.4%); 2 (15); 3 (12.9); 4 (10.5); 5 (9.2); 6 (9.8); 7 (7.3); 8 (5.1); 9 or more (8.7). The percent of mothers who reported one or more stillbirths was 9.9 and 10.7% reported one or more abortions. The 985

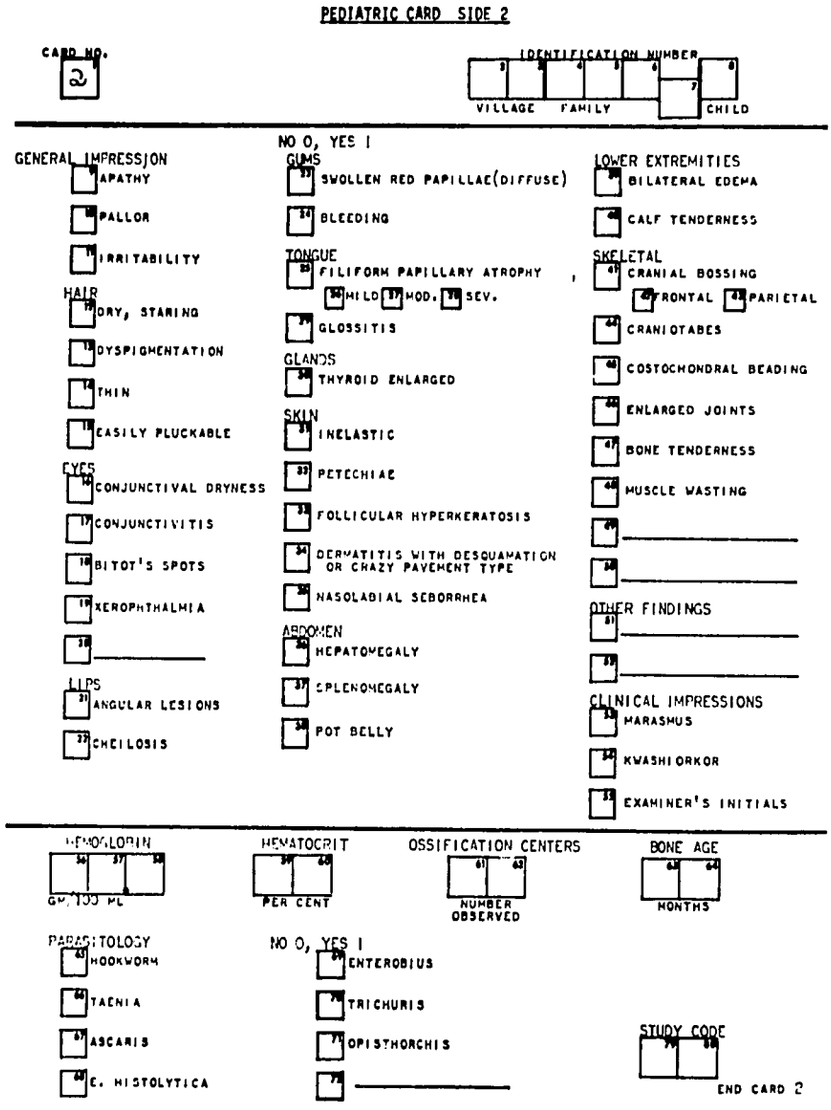

FIG. 4. Card 2 used in listing data.

mothers reported a total of 4,071 live births; 596 (14.6%) of these children had died. Of these, 66% died under 1 year of age, 23% between 1 and 5 years of age, and 11% over 5 years of age.

The anthropometric data obtained on the village children are presented in Table 2 and Figs. 6 and 7. These data are consistent with previously published and unpublished reports of the lengths and weights of poorly nourished Thai preschool children (7, 8, and J. D. Wray, personal communication). All of the anthropometric indices measured indicate that the Chiang Mai village children of this study were severely retarded in growth and development. It can be seen that bone ages derived from the Fels standards (9) for hand–wrist X-rays of boys and girls support this conclusion. Equivalent bone ages for children up to 1 year of age were essentially normal but by the time the Thai village children reach 4 years of age, they are approximately 1 year behind in the ossification of their hand–wrist bones.

Middle-class Bangkok preschool children–

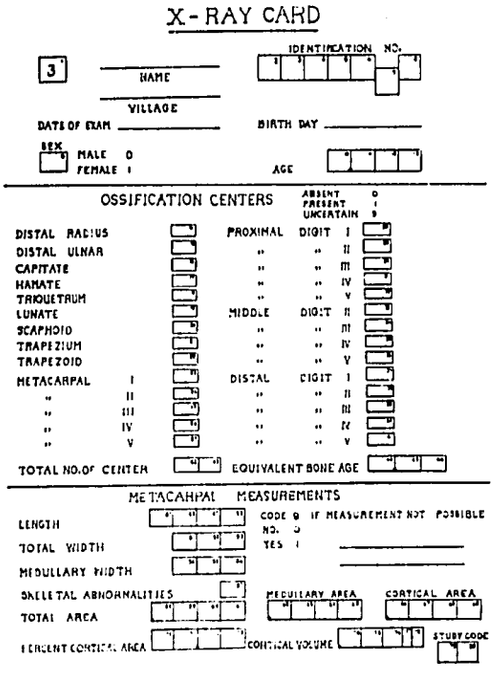

FIG. 5. Card 3 used in listing hand–wrist X-ray data.

baseline data. Anthropometric measurements were obtained from 315 preschool, middle-class Bangkok children. The children, aged 3 years and older, were obtained from a private kindergarten and two municipal preschool day-care centers which charge for their services. They probably came from wealthier families than the younger children who were examined in three well-baby clinics, two at city hospitals and one at a municipal health center, which do not charge for their services. Hand–wrist X-rays were obtained on 261 of them. The data obtained are presented in Table 2 and Figs. 6 and 7 and are consistent with previous reports of the lengths and weights of well-nourished Thai children (8, Wray, personal communication). For all of the anthropometric measurements made, the values obtained for the middle-class children were greater than for the village children. This was particularly true for equivalent bone age, length, weight, and head, chest and arm circumferences. The hand–wrist X-rays indicated that the development of ossification centers was normal for the goups of middle-class children studied with the possible exception of the 4–5 year olds. This may have been in part a reflection of the relative insensitivity of evaluations of hand–wrist X-rays in this age group to measure bone age as compared to younger groups.

Preventarium preschool children - length and weight data. There is in Bangkok an institution called a Preventarium designed to care for the well babies of poor tubercular and leprous mothers. The institution has excellent physical facilities and houses approximately 145 babies up to 5 years of age. It has a staff of 60 including a full-time pediatrician. The children receive abundant quantities of food each day in 3 meals and 2 snacks. Their housing and medical care are excellent and of great importance each child receives considerable personal attention. Weights and lengths are measured at least once a month on each child. These data were made available to us.

In Figs. 6 and 7, 12-month changes in length and weight of groups of these children from the time they entered the Preventarium are contrasted with the growth changes of children in the test villages and the middle-class Bangkok children. The village children between 0.5 and 4.5 years of age grew approximately 6.7 cm a year. The median growth of North American children of the same age is about 8.6 cm a year. The average increase in length of the Preventarium children during the first year they were in the institution was 12.4 cm. In contrasting weight changes with age for these groups of children, it is interesting to note that the marked increase in change of length of the Preventarium children 2.5 to 4.5 years was not accompanied by similar weight changes.

TABLE 1
Hemoglobin and hematocrit values for Chiang Mai village children and their mothers

	Hemoglobin		Hematocrit	
	% deficient	% low	% deficient	% low
Mothers	9.7	12.7	1.8	21.3
Children				
Age 1–1.9	20.2	26.7	1.9	12.6
Age 2–2.9	7.5	19.2	1.1	3.4
Age 3–3.9	4.6	10.7	0	4.3
Age 4–4.9	3.1	10.1	1.4	1.4

For hemoglobin (in g/100 ml) deficient <10, low 10–10.9. For hematocrit (as %) deficient <30, low 30–37 for mothers, 30–33.9 for children.

TABLE 2
Thai village and middle-class children anthropometric measurements

Age	No. of children	Length, cm	Weight, k	Bone age, year	Head circum, cm	Chest circum, cm	Arm circum, cm	Triceps skinfold, mm	Subscap skinfold, mm
				Village					
<1 (0.71)	116	66.2±3.5	7.3±1.3	0.65±0.28	42.6±1.9	43.1±2.7			
1-1.99 (1.54)	276	74.7±4.4	8.9±1.3	1.35±0.56	45.1±1.5	46.0±2.3	13.6±1.0	7.4±1.3	5.0±1.2
2-2.99 (2.49)	287	81.7±4.6	10.6±1.4	2.05±0.65	46.6±1.8	48.4±2.4	14.0±1.0	8.0±1.4	5.3±1.3
3-3.99 (3.50)	290	89.8±4.3	12.3±1.3	2.68±0.77	47.4±1.3	49.9±2.4	14.4±1.0	8.0±1.4	5.2±1.3
4-4.99 (4.52)	296	96.0±4.3	13.7±1.5	3.36±0.86	47.8±1.3	50.9±2.3	14.6±1.0	7.6±1.5	4.9±1.2
				Middle-Class					
<1 (0.65)	54	69.5±3.4	8.1±1.2	(43) 0.77±0.43	43.5±1.5	44.8±2.2			
1-1.99 (1.46)	68	78.4±4.3	10.4±1.7	(53) 1.65±0.70	46.2±1.7	48.0±2.1	14.3±1.0	7.6±1.2	5.6±1.0
2-2.99 (2.54)	50	88.3±4.2	11.9±1.5	(42) 2.57±0.90	47.9±1.2	49.9±1.8	14.8±0.8	8.3±1.2	5.6±1.0
3-3.99 (3.52)	58	96.8±5.9	14.2±2.2	(52) 3.63±1.08	48.8±1.3	51.1±2.4	15.5±1.6	8.2±1.7	5.7±1.6
4-4.99 (4.51)	81	102.0±5.2	15.0±2.1	(71) 3.80±0.97	48.7±1.4	51.4±2.3	15.4±1.3	7.8±1.2	5.1±0.9

Figures in ( ) in column 1 are mean ages and in column 5 are the number of middle-class children whose hand-wrist X-rays were measured. Values include means ± SD.

Discussion

The purpose of this paper has been to describe a large-scale field study of rice fortification now underway in villages of northern Thailand and to present some of the baseline data obtained in the initial examination of the village preschool children and their mothers. On the basis of the data collected in the initial studies, the villages were assigned to the five study goups in such a way that no significant differences were apparent among the people of each group for the parameters measured.

Because Thailand has a higher standard of living than most countries of Asia, there is less malnutrition there than in some of its less fortunate neighbors. There are some who question doing nutrition studies in Thailand because of this and we have frequently heard nutritionists from industrialized countries question whether there really is a significant amount of protein–calorie malnutrition in Thailand. It is unfortunate that such individuals can have their perspective so easily distorted by the specter of rampant disease and acute malnutrition in other countries. It would clearly be foolish to do fortification studies in a population which could not nearly meet its nutrient energy requirements or in which disease existed in unchecked epidemics. On the other hand, it would be equally foolish to do fortification studies in a country in which there was little evidence of nutritional disease and in which dietary surveys indicated little cause for concern. This has not been true in Thailand. Although the availability of calories appears substantial, there is considerable evidence that many people, particularly preschool children, do not consume adequate calories. Furthermore, protein consumption and the intake of a

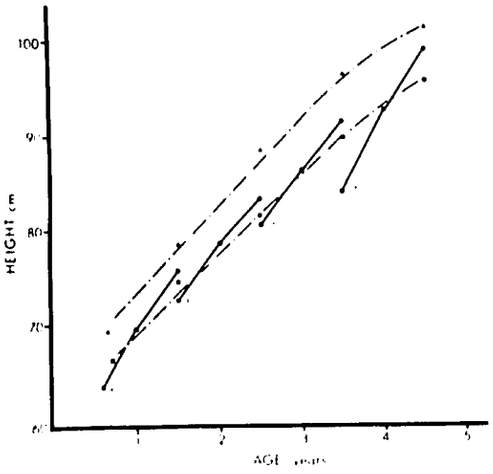

FIG. 6. Changes in height for age of Thai children: triangles, middle-class children; squares, village children; circles, Preventarium children.

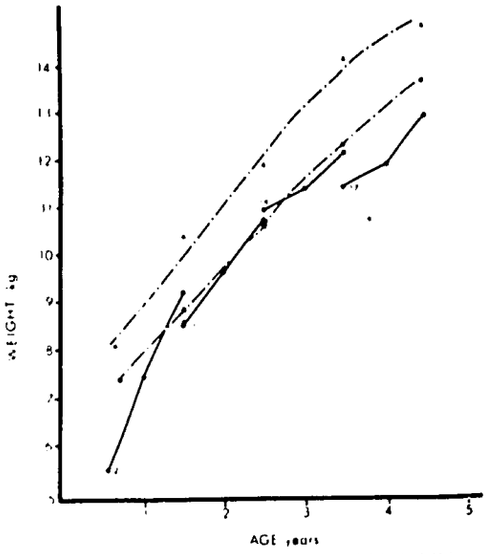

FIG. 7. Changes in weight for age of Thai children: triangles, middle-class children; squares, village children; circles, Preventarium children.

number of nutrients, particularly thiamin, riboflavin, vitamin A and in some areas iodine and other elements is poor. It is not difficult to find substantial numbers of people with clinical manifestations of these deficiencies in the Chiang Mai area. Malnutrition is generally associated with poor reproductive performance, high rates of infant and preschool child mortality, and poor growth rates. As can be seen in the data presented, these conditions are all present in the population being studied. It is clear that the small size of the village children does not have a simple genetic explanation since it can be seen in Table 2 and figs. 6 and 7 that the village children were considerably smaller in length, weight, and bone development and all other anthropometric indices measured than middle-class Bangkok children.

It is assumed that the developmental differences in the village and Bangkok children cannot be attributed only to diet. They are affected by many other environmental factors such as the delivery of medical care and the quality of housing and sanitation which have not been altered in this study. It is impossible at this time to estimate the percent of the developmental lag observed which is due to poor nutrition. It is possible that the effects of improved nutrition might be entirely or in part masked by undesirable environmental effects. Where such is true, it would be essential that these effects be recognized and that action to correct them accompany nutrition programs.

The data from the Preventarium indicate that when such is done the effects on growth of Thai children, the size of those in the Chiang Mai villages may be considerable. When provided with a full health program, the catch-up growth of the Thai children in the Preventarium for a year, as determined by measuring length, was considerably greater than the average growth of North American children.

Future reports will describe the effects of the fortification program set forth in this paper. The potential for improving health and accelerating development in poor Thai children and by extension in deprived children throughout the world by the proper kinds of intervention is clear and exciting.

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