NUTRITION AND AGRICULTURAL DEVELOPMENT

Significance and Potential for the Tropics

Edited by

Nevin S. Scrimshaw
Massachusetts Institute of Technology

and

Moisés Béhar
World Health Organization

PLENUM PRESS . NEW YORK AND LONDON

8

Definition of the Nutrition Problem in the Labor Force

Fernando E. Viteri

Biomedical Division
Institute of Nutrition of Central America and Panama
Guatemala City, Guatemala

Arteaga made reference to the fact that many of the adult laborers in Latin America are suboptimally nourished, and proposed a series of measures aimed at correcting this situation. I will present a very brief summary of our findings on the nutrition, body composition, work performance, and energy balance of rural agricultural workers in Guatemala to illustrate some of the negative interactions between nutritional deficiencies and work performance, productivity, and socio-economic development. The characteristics that stand out most clearly among male agricultural laborers in a tropical, developing area are their small size, leanness, slow working pace, and, in the lowlands, often their pallor. Over 30% of them have hookworm infection (1). Dietary surveys indicate that their calorie intakes are frequently less than 2700 per day (2), with protein intakes ranging between 70 and 90 g per day (2,3). Often riboflavin, folate, and vitamin A are inadequate (2). Further observations and inquiries bring about other so-called characteristics: They are often referred to as "lazy, inefficient workers," and as people who find it difficult to engage in after-work activities aimed at individual or communal betterment. In other words, they are apathetic human beings.

We investigated some of the relations between these characteristics and nutrition, starting with the two nutrients that seemed most limiting: calories and iron.

Table I. Body Composition of Supplemented and Unsupplemented Agricultural Laborers in the Highlands of Guatemala

Subjects	Body weight (kg)	Height (cm)	Lean body mass (g/cm)	Muscle mass (g/cm)	Adiposity (g/cm)
Supplemented	60.1[a]	161	322	153	50
(N = 18)	1.3[b]	1	7	6	3
Unsupplemented	50.8	158	294	119	26
(N = 18)	1.0	1	6	6	1

[a]Mean.
[b]SE.

CALORIES

From previous work (3–5), as well as from work in progress (6), the following specific points appear pertinent.

1. Agricultural workers subsisting on an average intake of 2700 calories per day have lower body weight, less adipose tissue, and reduced lean body mass (LBM) and muscle mass compared to similar agricultural workers receiving a nutritional supplement that increased their calorie intake to 3550 per day (Table I). It is worth noting that none of the latter workers were obese.

2. Supplemented laborers also have more total circulating hemoglobin, and display superior performance on tests of physiological functions indicative of physical work capacity, including maximal oxygen consumption ($\dot{V}O_2$ max.) and cardiac output at $\dot{V}O_2$ max. In Table II, both populations have been

Table II. Pertinent Variables Involved in Work Performance of Agricultural Workers in Guatemala (Grouped by Lean Body Mass)

	Lean body mass (kg)		Hemoglobin concentration (g/100 ml)		Total circulating hemoglobin (g)		Maximal O_2 consumption (ml/min)		Maximal cardiac output[a] (liters/min)
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean
< 45 (N = 15)	42.7	1.5	15.0	1.7	622	87	2145	308	16.1
45–49.9 (N = 19)	47.3	1.4	15.8	1.4	721	75	2302	253	17.0
50–54.9 (N = 16)	52.6	1.4	15.6	1.2	752	73	2498	335	18.0
55 and + (N = 14)	58.2	2.8	16.2	0.8	917	117	2934	269	20.5

[a]Calculated on the basis of Hermansen, *Acta Physiol. Scand., Suppl.* 339, 1973.

grouped into LBM categories to indicate the relationship between body composition and physiological performance in these populations.

The linear regression and scattergram between LBM and $\dot{V}O_2$ max. is shown in Figure 1. Table III presents the interrelation between total circulating hemoglobin and $\dot{V}O_2$ max. in absolute terms. This relationship disappears when the last variable is expressed as per kilogram of lean body mass (Table IV). This, plus the fact that the correlation coefficient between LBM and $\dot{V}O_2$ max. is higher than between total circulating hemoglobin and $\dot{V}O_2$ max. (r = 0.692 and r = 0.534, respectively), suggests that the primary effect of caloric supplementation in these populations has been an increase in LBM, which possibly induced elevations in both $\dot{V}O_2$ max. and total circulating hemoglobin. This type of response has also been documented in children recovering from malnutrition, whose rate of increase in total circulating hemoglobin is governed by the rate of increment in LBM (7,8).

The increment in LBM and muscularity that accompanied the nutritional supplement made the laborers better able to handle work situations that demanded strength and repeated large muscle action. Being not only short in stature but also having a relatively reduced muscle mass and LBM, suboptimally nourished workers do not respond to high-energy-demanding work situations with full efficiency. Furthermore, in active individuals, LBM correlates highly significantly with $\dot{V}O_2$ max. and tissue oxygen delivery (cardiac output and total circulating hemoglobin) (Figure 2).

The mechanisms by which calorie supplementation brought about such changes in LBM are not yet clear. One possible mechanism could be increased activity, leading to an effect similar to that of physical training. Caloric supplementation may also have played an important role in the complex phenomenon of physical endurance, which is markedly dependent on availability of energy for muscle action derived either from body energy reserves (for the most part, adipose tissue) or from available food energy. The following data indicate that food energy may have an important role in defining the activity level of agricultural populations.

3. Supplemented laborers reach a new energy equilibrium by increasing their energy expenditure. This is achieved almost exclusively by becoming more active physically.

Results of time/motion studies in both supplemented and unsupplemented laborers indicate that the latter group lost weight during the period of observation when they increased their energy expenditure above their level of intake. In spite of greater effort, they were unable to continue to be active after work; they usually took long naps in the afternoon. In contrast, the supplemented men were more active, worked at a higher energy expenditure level (3–5), and did not interrupt their work in midafternoon. Furthermore, in spite of spending more calories than the unsupplemented group, they did not lose significant

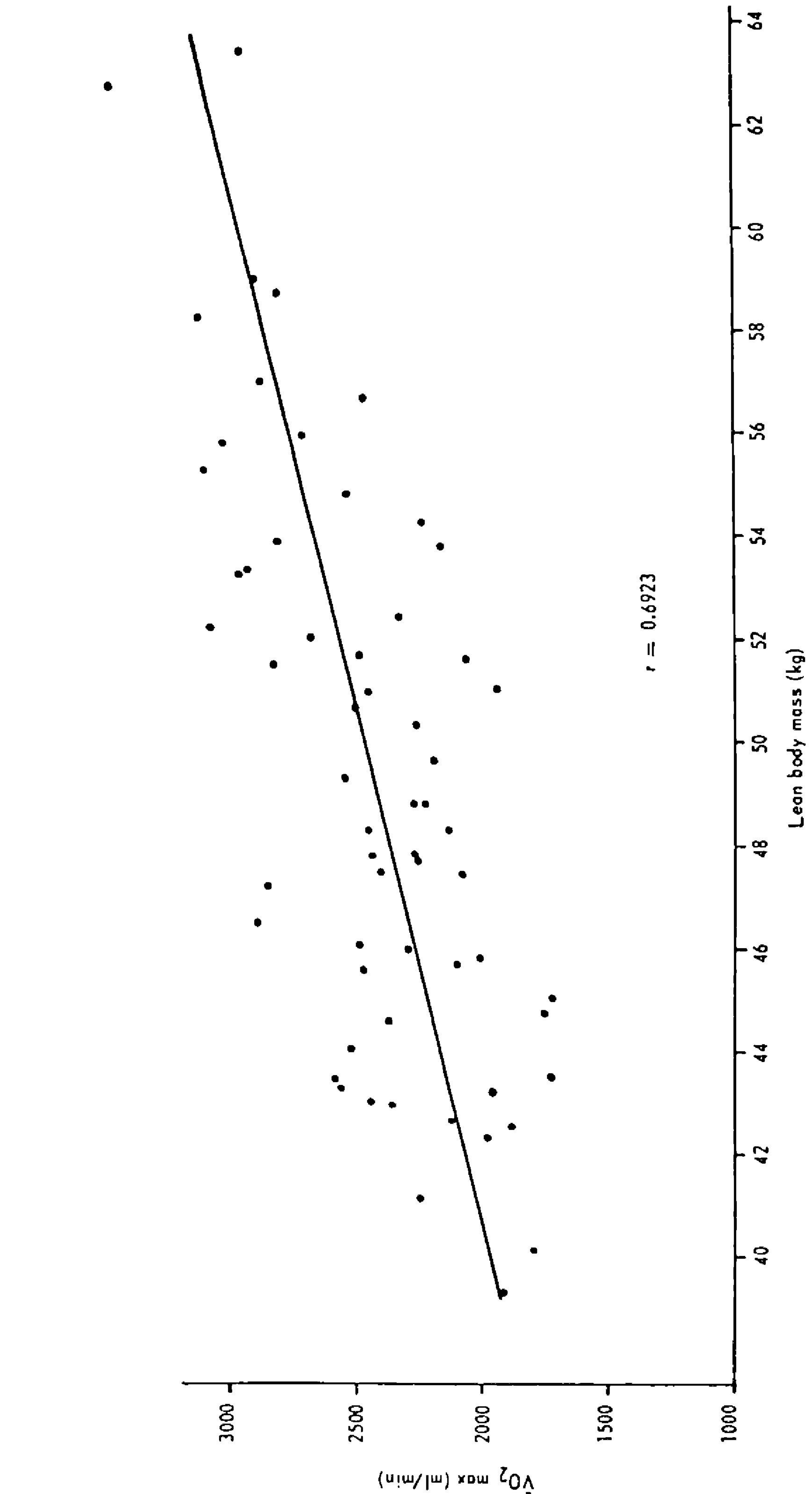

FIG. 1. Lean body mass and maximal oxygen consumption of agricultural laborers in Guatemala.

Table III. Maximal Oxygen Consumption ($\dot{V}O_2$ max.) for Different Values of Total Circulating Hemoglobin of Agricultural Workers in Guatemala

Total circulating hgb. (g)	N	$\dot{V}O_2$ max. (ml/min)	
< 600	7	2009[a]	184[b]
600–699	20	2302	333
700–799	20	2446	341
800–899	11	2538	275
900+	6	2931	336

[a]Mean.
[b]SD.

amounts of weight (Table V). Additional data derived from these studies are that one standard, representative task requires approximately 990 calories spent in physical activity during a period of four to six hours.

Based on this and other available information, the following generalizations can be made (Figure 2):

a. The average agricultural laborer in Guatemala requires 1612 calories per day in order to compensate his basal energy expenditure. Such energy expenditure can be further divided into that spent during a night's sleep (8 hours), which amounts to 540 calories, and 1072 calories that are expended during the rest of the 24 hours.

b. He requires 990 extra calories for the activity increment involved in performing one standard, representative task for 4 to 6 hours. Adding these energy expenditures to that in sleep, plus performance of one task in the

Table IV. Maximal Oxygen Consumption per kilogram Lean Body Mass for Different Values of Total Circulating Hemoglobin of Agricultural Workers in Guatemala

Total circulating hgb. (g)	N	$\frac{VO_2 \text{ max. (ml/min)}}{\text{LBM (kg)}}$	
< 600	6	46.2[a]	5.3[b]
600–699	18	49.6	6.9
700–799	19	48.7	6.0
800–899	10	49.4	4.6
900+	6	49.8	4.1

[a]Mean.
[b]SD.

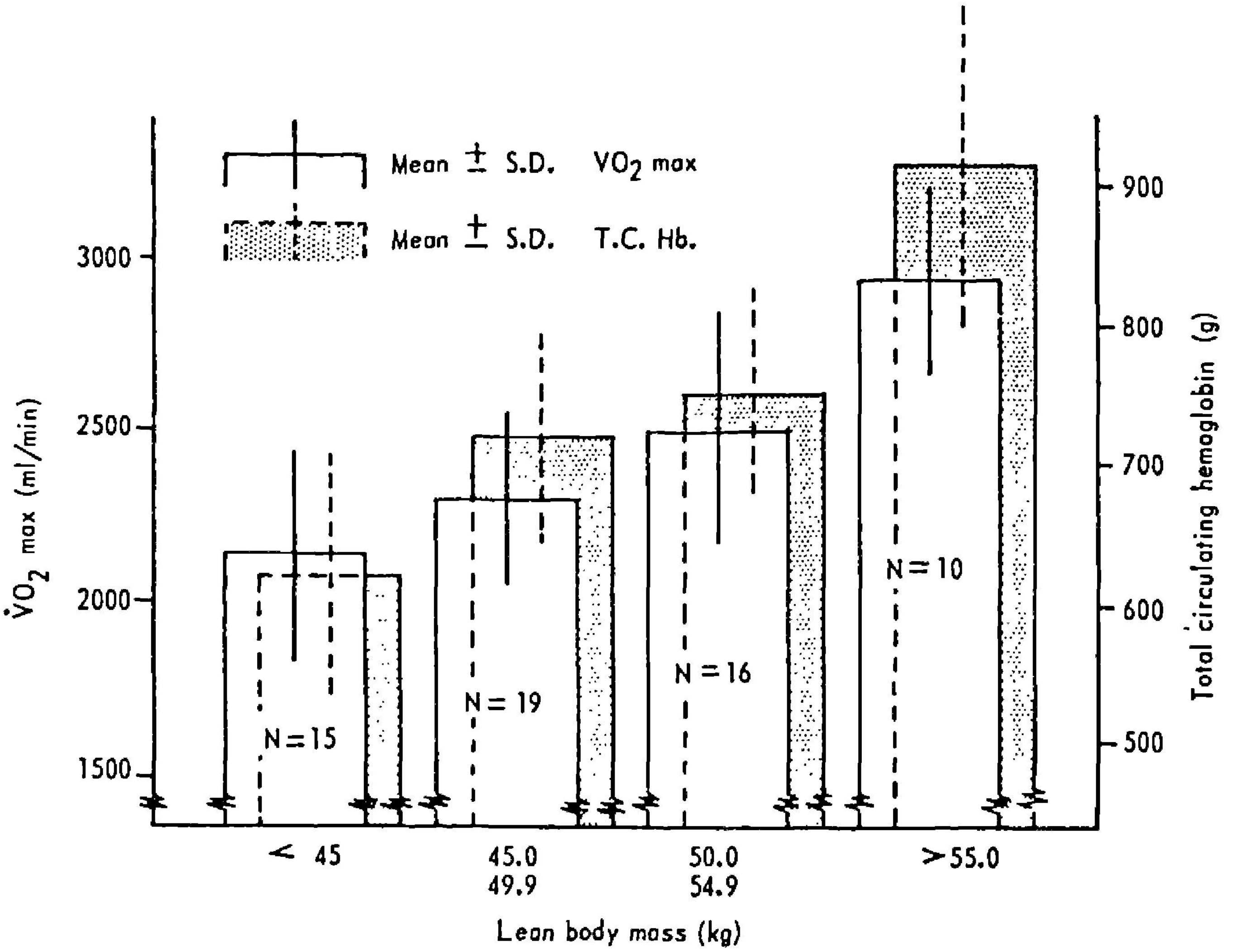

FIG. 2. Maximal oxygen consumption and total circulating hemoglobin for different amounts of lean body mass of agricultural laborers in Guatemala.

Table V. Caloric Intake, Expenditure, and Balance, and Body Weight Changes of Agricultural Workers in Guatemala (Period of Observation = 3 Days per Subject during Time/Motion Studies)

	Groups			
	Supplemented (N = 18)		Unsupplemented (N = 18)	
	Mean	SE	Mean	SE
Energy intake (cal/day)	3555	168	2695	118
Energy expenditure (cal/day)	3694	109	3396	128
Energy balance (cal/day)	−138	180	−707	110
Change in weight (g/3 days)	−29	64	−346	174
Expected weight change (g/3 days)[a]	−22	29	−316	46

[a] 1 g of weight loss is assumed to yield 6.2 calories.

morning, it becomes evident that a laborer who eats 2600 calories per day has spent all available food energy for performing that task. Consequently, he must remain very inactive after work in order to maintain energy balance. The only way he can achieve this is by spending this time napping or just sitting, doing nothing. Another alternative is, of course, to do less than one task a day, or do an inadequate job at it.

From our studies it is also evident that an active worker engaged in

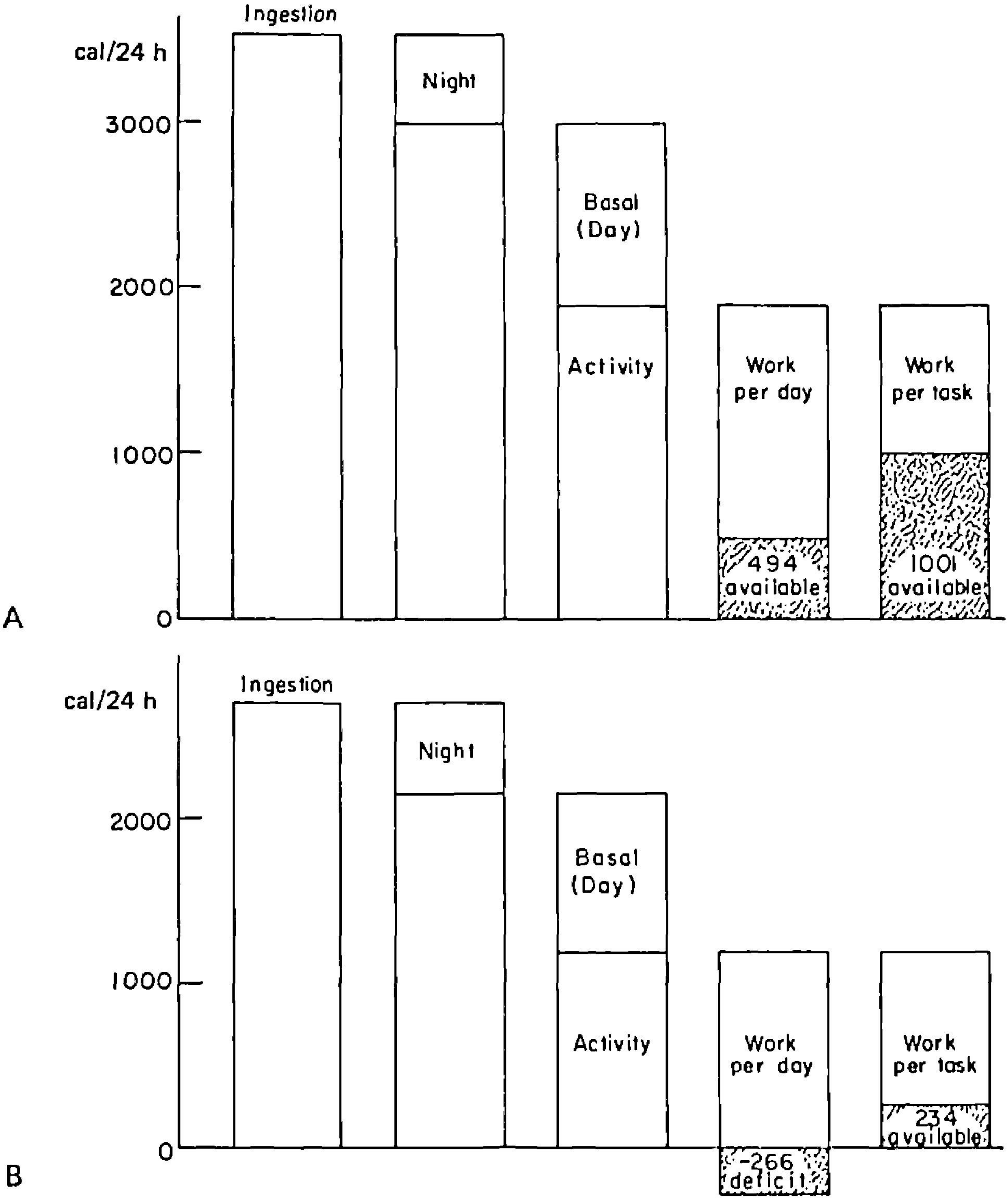

FIG. 3. Energy balance of supplemented (A) and unsupplemented (B) agricultural workers in Guatemala. Values represent an average day and are broken down into different energy expenditure categories.

agricultural activities on an 8-hour-per-day basis spends close to 1500 calories on top of his basal caloric expenditure in farming chores. The total energy expenditure comes up to 3110 calories in 16 hours, there being 8 additional after-work hours left. If a laborer is to remain active during this time, he requires at least 1 calorie per minute beyond his basal energy expenditure, or nearly 480 additional calories. The total energy expenditure would then amount to 3590 calories per day. The calorically supplemented group working an 8-hour day spent very close to this amount (Table V). It is obvious that, thermodynamically, the unsupplemented group (eating 2700 calories) could not be efficient workers on an 8-hour-per-day work schedule, and that on a task-per-day basis, their after-work activity is reduced to essentially nil (Figure 3).

This also explains why hired laborers are not contracted on an 8-hour-per-day schedule and why the agricultural labor force is often characterized as "lazy and apathetic," without the drive to participate in after-work activities.

The actual work pattern of agricultural laborers demands effective use of strength, near maximal work capacity, and endurance. For example, the use of a hoe, an ax, or a machete demands strength and endurance; walking up a hill with a load also demands near-maximum effort. Such efforts, however, take up only a short period throughout the day because most manual laborers work at close to one-half of their maximum aerobic capacity (½ $\dot{V}O_2$ max.).

In brief, insufficient caloric intake imposes a ceiling on the total energy expenditure in agricultural laboring populations that, in the long run, results in low productivity, which in turn contributes significantly to socioeconomic underdevelopment. Furthermore, by making the individual less muscular, caloric insufficiency also renders him less able to perform high-energy-demanding tasks,

Table VI. Maximal Predicted Work Load (cal/min) That Can Be Sustained by Individuals with Various Levels of Hemoglobin Concentration and Three Different Maximal Cardiac Outputs

Hgb. concentration (g/100 ml blood)	Maximal work load (cal/min) for maximal cardiac output		
	15	20	25
4	3.2	4.2	5.3
6	4.8	6.4	8.0
8	6.4	8.5	10.6
10	8.0	10.6	13.2
12	9.6	12.7	15.9
14	11.1	14.8	18.5
16	12.7	17.0	21.2

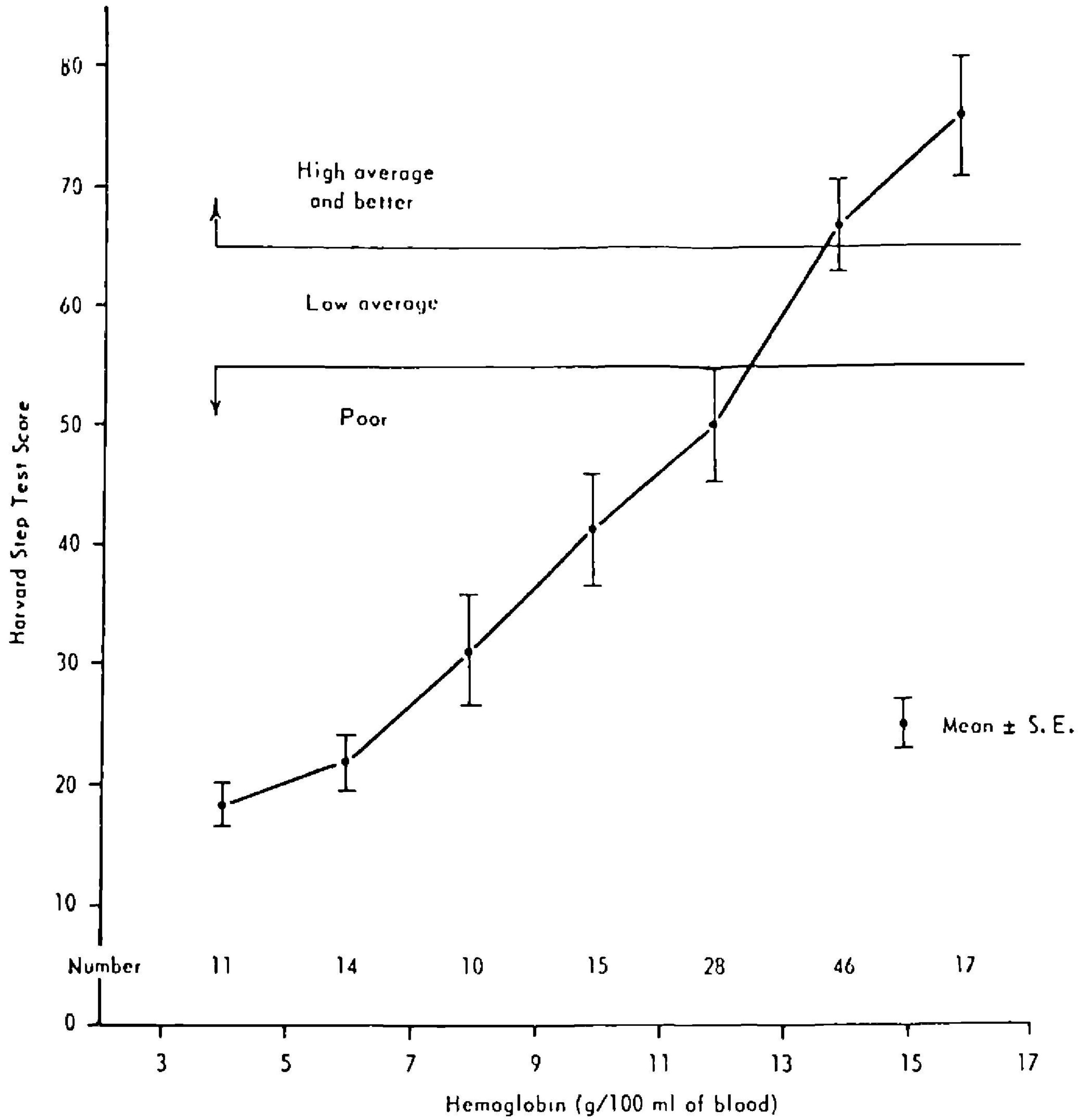

FIG. 4. Physical fitness in relation to hemoglobin concentration in Guatemalan agricultural workers.

and his smaller LBM also limits his maximal oxygen delivery to tissues and, therefore, acts synergistically with anemia.

IRON

Chronic iron deficiency anemia diminishes tissue oxygen delivery for a given cardiac output. A known compensating mechanism for anemia is an increased cardiac output at rest and during submaximal work situations. This results in meeting tissue oxygen demands by means of a more rapid circulation of blood, with reduced levels of hemoglobin. However, maximal cardiac output is not

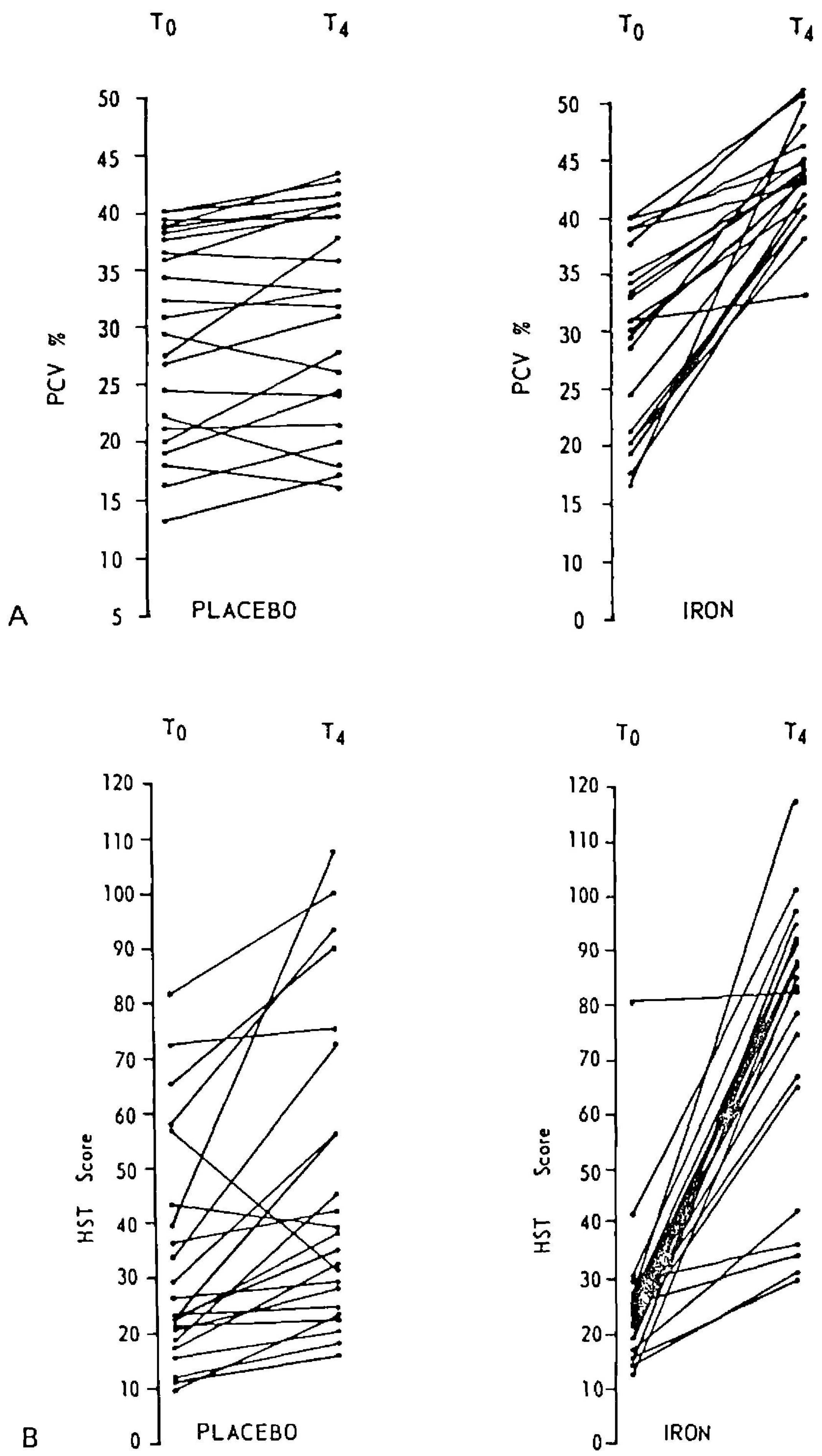

FIG. 5. Changes in packed cell volume (PCV) and in Harvard Step Test score (HST score) in two groups of Guatemalan agricultural workers, before (A) and after (B) 4 months of treatment with placebo or with oral iron.

increased in anemia, so that maximal, or near-maximal, oxygen delivery to tissues is reduced. The end result of anemia on work performance will necessarily depend on two factors: (a) tissue oxygen demands, and (b) maximal oxygen delivery capacity. The first of these factors is directly proportional to the intensity of physical effort; the second is inversely proportional to the degree of anemia, or directly proportional to the hemoglobin concentration in the blood. It is also directly proportional to the maximal cardiac output. This last variable, as described earlier, is proportional to LBM in active populations.

These basic concepts allow us to predict the maximal energy output a laborer can sustain for a given period of time, on the basis of body size and hemoglobin concentration (9) (Table VI). Furthermore, the lack of proper understanding of these physiological considerations has resulted in contradictory reports on the effect of anemia on physical working capacity and productivity.

Our own experience in evaluating physical fitness in active populations with anemia before and after treatment with oral iron (10–12) indicates that the capacity to perform a short, near-maximal effort correlates inversely, and very significantly, with the degree of anemia (Figure 4). Treating the anemia without any other intervention results in a marked improvement of this physiologic test (Figure 5).

In summary, anemia decreases the capacity to perform energy-demanding tasks. Mild to moderate degrees of anemia (hemoglobin concentrations between 9 and 13 gm per 100 ml of blood in adult males) only decrease the capacity to perform hard to extreme physical efforts. More severe anemia impairs performance during even mild efforts.

Anemia and insufficient caloric intake thus decrease work capacity by different mechanisms, both leading, finally, to decreased productivity and to hampered agricultural and general socioeconomic development.

REFERENCES

1. Viteri, F. E., Guzmán, M. A., and Mata, L. J., 1973, Anemias nutricionales en Centro América; influencia de infección por uncinaria, *Arch. Latinoam. Nutr.* 23: 33–53.
2. *Nutritional evaluation of the population of Central America and Panama. Regional summary*, Institute of Nutrition of Central America and Panama (INCAP) and Nutrition Program, Center for Disease Control (formerly Interdepartmental Committee on Nutrition for National Development). Washington, D.C., U.S. Department of Health, Education and Welfare, 1972, 165 pp. (DHEW Publication No. (HSM) 72-8120).
3. Viteri, F. E., 1971, Considerations on the effect of nutrition on the body composition and physical working capacity of young Guatemalan adults, *in: Amino acid fortification of protein foods*, N. S. Scrimshaw and A. M. Altschul (eds.), M.I.T. Press, Cambridge, Massachusetts, pp. 350–375.
4. Viteri, F. E., Torún, B., Galicia, J. C., and Herrera, E., 1971, Determining energy costs of agricultural activities by respirometer and energy balance techniques, *Am. J. Clin. Nutr.* 24: 1418–1430.

5. Viteri, F. E., and Torún, B., 1975, Ingestión calórica y trabajo físico de obreros agrícolas en Guatemala. Efecto de la suplementación alimentaria y su lugar en los programas de salud, *Bol. Of. Sanit. Panam.* 78: 58–74.
6. Viteri, F. E., Torún, B., and Immink, M. D. C., 1975, Nutrition and productivity. Effect of energy intake and supplementation on the productivity of agricultural workers in Central America. Preliminary report. Presented at the 14th Meeting of the Pan American Health Organization (PAHO), Washington, D.C., Advisory Committee on Medical Research.
7. Viteri, F. E., and Alvarado, J., 1970, Aspectos fisiológicos y respuestas adaptivas en la desnutrición calórica y en la desnutrición proteínica, *Rev. Col. Med. Guatemala* 21: 175–230.
8. Viteri, F. E., and Pineda, O., 1971, Effects on body composition and body function, *in: Famine. A symposium dealing with nutrition and relief operations in times of disaster,* G. Blix, Y. Hofvander, and B. Vahlquist (eds.), Symposia of the Swedish Nutrition Foundation IX, Almqvist and Wiksell, Uppsala, pp. 25–40.
9. Viteri, F. E., and Torún, B., 1974, Anaemia and physical work capacity, *Clin. Haemat.* 3: 609–626.
10. Viteri, F. E., 1973, Physical fitness and anemia, *in:* Malnutrition and functions of blood cells, N. Shimazono and T. Arakawa (eds.), Proceedings of the Symposium sponsored by the Malnutrition Panels of the United States–Japan Cooperative Medical Science Program, The National Institute of Nutrition, Tokyo, Japan, pp. 559–583.
11. Viteri, F. E., 1973, Hematological status of the Central American population: Iron and folate deficiencies, *12th Meeting of the Pan American Health Organization (PAHO),* Washington, D.C., Advisory Committee on Medical Research.
12. Cifuentes, E., and Viteri, F. E., 1972, Physical fitness, iron deficiency and anemia in agricultural laborers of Central America, *Fed. Proc.* 31: 719 (Abstract 2843).