Iron deficiency anemia and the productivity of adult males in Indonesia[1,2]

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ABSTRACT Approximately 88% of adult male workers on a rubber plantation in West Java, Indonesia had hookworm infection, and over 45% were anemic as judged by a hemoglobin below 13 g/100 ml. Hemoglobin values and Harvard Step Test (HST) performance for both tappers and weeders were significantly correlated. The rubber tappers were paid by their work output, and their earnings correlated with hemoglobin levels. Morbidity and hemoglobin levels were also correlated. Caloric intakes were not correlated with either work output or HST performance. Treatment with 100 mg of elemental iron for 60 days resulted in a significant improvement in hematological status of the anemic individuals and in their HST performance, work output, and morbidity. Both treatment and placebo groups received a daily incentive payment of 15 rupiahs, equivalent to 5 to 7% of minimum daily wages. This sum, spent largely on food, resulted in added intakes of 3 to 5 mg of available iron and 50 mg of vitamin C. This is believed to explain a significant but lesser improvement in hemoglobin, HST performance, work output, and morbidity in the anemic placebo group. In an untreated subsample to whom no payment was given, no change in hemoglobin, hematocrit, work performance, HST score, or disease morbidity occurred. After income supplementation was stopped, hemoglobin and hematocrit levels and related changes reverted to initial levels within 30 days in the placebo groups, but were unchanged in the iron-treated groups. The cost of the iron supplementation was small compared with the economic benefits of increased productivity and lowered morbidity. *Am. J. Clin. Nutr.* 32: 916–925, 1979.

Because anemia does not have overt, specific symptoms and is diagnosed by laboratory procedures, it is not ordinarily recognized by lay persons as a disease. Its symptoms are subtle, chronic, and associated with those of other diseases. It can impair exercise performance (1–5) and is a potentially important determinant of labor productivity.

In the tropics, the combination of blood loss from parasitic infection, especially hookworm (6–8), and low availability of dietary iron (9) is the most common cause of iron deficiency anemia. Iron deficiency anemia affects physical capacity by reducing the availability of oxygen to the tissues, which, in turn, affects cardiac output and the heart. It also reduces the efficiency of oxygen exchange in muscle and myoglobin. Experimental evidence suggests that susceptibility to infection may be increased because myeloperoxidase, an iron-containing enzyme that plays a vital role in the killing power of leucocytes, is also affected (10, 11).

In a pilot labor productivity study in Indonesia, an attempt was made to measure the effect of correcting the iron deficiency of 100 road construction workers. Because of the high dropout rates and the cessation of many work activities caused by heavy monsoon rains, data were obtained on only 22 iron-treated and 20 placebo-treated workers. The results, however, indicated that physical performance of anemic workers could be improved by administration of 100 mg of elemental iron daily for 4 weeks. Productivity per se was not measured, but only physical endurance during the Harvard Step Test (HST). The study indicated a significant correlation among hemoglobin, hematocrit, and

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HST scores, although other nutrient intakes, including that of calories, did not correlate with the HST.

This experience provided the basis for the current intervention program among rubber plantation workers to determine: (*1*) whether anemia in low-income workers affected physical endurance, their actual productivity, and their resistance to infection, and (*2*) whether iron supplementation could diminish iron deficiency anemia and raise work output in this population.

Materials and methods

Characteristics of the population

A total of 302 male plantation workers, 16 to 40 years old, selected randomly from a list of 400 workers, were divided into anemic (152) and nonanemic (150) groups on the basis of a hematocrit below or above 38%. The majority of the workers were tappers who collected latex from 400 to 500 rubber trees per day, while weeders (about 30% of the total work force) were mainly responsible for clearing and digging jungle roots around the rubber trees, completing an average of 70 to 100 m^2 area per day.

Seventy tappers and 83 weeders received 100 mg of ferrous sulfate in dextrose daily for a period of 60 days, while the control group (86 tappers and 63 weeders) were given an identical looking dextrose tablet.[7] Neither the workers nor those administering the tablets knew who was receiving the iron or placebo. Although some workers had dark colored stools, they did not know the significance of this, and by design, no attention was paid to it.

To encourage participation, a payment of 15 rupiahs (approximately 3¢ U.S.) was given daily to workers in both groups when the tablet was taken. Nevertheless, 41 individuals did drop out of the program, and an additional 10 subjects were eliminated from the final analysis because they received other medication that might have prejudiced the results. A subgroup, consisting of 51 workers, who received no iron, placebo, or income supplement, was also tested hematologically before and after the intervention.

Medical examination

Examinations were conducted before and immediately after the intervention study, and the physician visited the site frequently during the study. Diseases reported by the subjects to have occurred in the 4 weeks before the first examination were recorded. These were characterized as acute (e.g., common cold, influenza, hepatitis); subacute (e.g., arthritis), or chronic (e.g., tuberculosis). They were scored on a scale of 0 to 3 according to severity and duration, and the figures were added to give a total morbidity score. In addition, general physical condition and nutritional status were scored. Absence from work for any reason, including "tiredness," was also recorded and scored. Height, weight, and mid-arm circumference were also recorded for each subject. Mean height for the sample was 157.4 ± 5.3 cm, and mean weight was 46.9 ± 4.9 kg. Mean age was 29.3 ± 7.5 years.

Laboratory examinations

Hematology. Using presterilized individual disposable lancets, finger-prick blood samples were taken for determination of hemoglobin and hematocrit, and blood smears were made to detect malaria parasites and define red cell morphology. Duplicate heparinized micro-hematocrit tubes were centrifuged at 15,000 rpm for 5 min. Hemoglobin was estimated as cyanomethemoglobin (12).

A 10 ml blood sample was drawn from all individuals with a hematocrit below 38 and put into a heparinized vacutainer tube for determination of other blood characteristics. Serum iron was measured by the World Health Organization method of plasma-iron determination, a modification of the technique originally described by Bothwell and Mallet (13). Total iron-binding capacity (TIBC) was tested by a method differing slightly from that originally described by Ramsay (14); that is, sulfonated bathophenanthroline was used for colorimetric determination. Blood film was stained with Giemsa solution for differential white blood cell count and examined microscopically for abnormalities in cell morphology related to deficiency disease, according to the method recommended by World Health Organization/Pan American Health Organization (15).

A 20% subsample, chosen at random from the iron-payment and placebo-payment groups, was reexamined after intervention for serum iron, transferrin, and TIBC levels. Hemoglobin and hematocrit were assessed not only 60 days after intervention in the entire group, but also at 91 and 100 days postintervention in 71 subjects chosen from the above. As a further control, the 51 untreated individuals were reexamined for hematocrit and hemoglobin after the intervention period.

Parasitology. Fecal samples were obtained from 10% of the workers. Immediately after collection, approximately 2 g of the sample were transferred to a 2-ounce bottle with screw top and thoroughly mixed with an equal amount of 1% formalin for later laboratory examination. Microscopic examination for the presence of parasites and eggs, and Stoll counts (16) for egg concentrations of samples positive for hookworm, were carried out by the Department of Parasitology, Faculty of Medicine, University of Indonesia.

Dietary interviews

The dietary data were collected by a trained nutritionist from a 25% subsample, using a combination of techniques from Burke (17), Klerks (18), and the Directorate of Nutrition of Indonesia. Each respondent described the kinds of food eaten and the frequency of eating during the previous weeks. Detailed questions then gave an aproximate amount of the foods consumed most frequently. Food items purchased from local food sellers were used as models, in addition to pictures of foods. Raw and cooked foods were weighed, and their nutrient content calculated from the Indonesian Food Composition Table (19). Because the menus were mostly

[7] The saccharine and tapioca placebo and the ferrous sulfate tablets were supplied by Kimia Farma, S.A., Jakarta.

simple and monotonous, the dietary intake data were quite reliable.

Dietary interviews of subjects after the income supplement had been provided indicated that this was largely spent on various edible leaves, as rice was rationed. The increased intake of 200 g of green leaves per worker provided an estimated 50 mg of ascorbic acid and about 8 to 10 mg of iron, with the availability of the latter increasing with the degree of anemia in the approximate range of 25 to 50% under these circumstances. Thus, the income supplement resulted in an added 3 to 5 mg of available iron.

Physical fitness and work capacity

The HST, as a simple test of physical capacity, was performed both before and after the intervention study. The procedure, evaluation, and interpretation followed the original method of Brouha et al. (20), except for the bench height. Dhanutirto and coworkers (21, 22) compared three benches of different heights and concluded that a 19-inch bench height rather than 20 inches was the most suitable for Indonesians.

Productivity measurements

To measure work output before and after intervention, two standard tasks were selected: the collection of wet latex by tappers and the weeding or excavation of roots and weeds between the rows of rubber trees. Tappers were paid daily on the basis of the weight of latex each man delivered to weighing huts. Each tapper worked 400 to 500 trees, and the distance between the trees was about 4 to 5 m. The output for weeders was measured by the area of trenches dug in parallel rows by each man.

Past records of payments to latex tappers provided a useful check on the income recorded during the intervention program and furnished another index of productivity. The topography, age, size, and variety of the trees were taken into account by analyzing only data from similar tree areas. Workers engaged in weeding were paid on a daily wage basis, which made productivity measurements more difficult. However, total area excavated during the 5-hr work day was measured for each individual. In addition, financial incentives were offered to those men who, in competitive groups of 10, could weed the largest area in 1 hr. The purpose was to measure the weeding capacity of these individuals under a strong incentive. It was impossible to extend the races beyond 1 hr because many of the workers were near exhaustion. Each group of 10 was matched for age, height, and experience. The winning group received the equivalent of 100% of the daily wage, with runners-up receiving decreasing portions of that sum.

Quality control was established by foremen who inspected each area to be measured. Weeders were warned that if quality was not maintained they could not continue in the competition. Measurements on 61 weeders were also conducted when they were not working under these financial incentives, and were unaware that their output was being measured. This work performance was compared with hemoglobin levels and HST performance by linear regression analysis to determine the relative influence of intervention and other factors.

Correlation of results

Data were analyzed statistically using IBM 1130 and UNIVAC 1108 computers. Significance of the differences between means was assessed by Student's t test and ANOVA.

Preintervention clinical results

Dietary intake

The main source of both calories and protein for plantation workers is rice. Cassava, coconut oil, sugar, and tubers provide most of the rest of their calories. The majority of workers consume acceptable to high levels of vitamin C and A from the fruits and edible leaves that are abundant in the jungle. Calcium, protein, and vitamin B intakes are low.

Anemic workers averaged 2000 ± 198.7 cal/day, 29.9 ± 2.8 g/day protein, 6.2 ± 0.8 mg/day iron, and 60.4 ± 20.6 mg/day vitamin C. Nonanemic workers consumed 2155 ± 202.8 cal/day, 31.9 ± 4.2 g/day protein, 7.4 ± 1.2 mg/day iron, and 100.7 ± 28.2 mg/day vitamin C. These differences between anemic and nonanemic subjects in this study were statistically significant ($P < 0.01$) for vitamin C only. The average intake of iron for all the workers fell in the deficient to low range.

Laboratory findings and clinical status

The prevalence of anemia, defined as a hemoglobin below 13 g/100 ml, in the entire sample of 399 was 45.4%; 6.3% of the sample had hemoglobin levels below 11 g/100 ml (Table 1), and 25% of the hematocrit values were less than 38%. About 30% of anemic workers had serum iron levels below 50 μg/dl, and TIBC was deficient in 65.6%. Hypersegmented granulocytes combined with oval macrocytes, suggestive of folate or B_{12} deficiency, were present in about 12% of the anemic men.

In the 10% subsample of 162 workers selected for stool examination, hookworm eggs were identified in 87.7%. A relationship was found between the severity of the infestation and hematocrit-hemoglobin levels (Table 2). *Ascaris lumbricoides* were reported in 48.8%; Trichuris in 63.4%; *Escherichia histolytica* in 8.6%; *Escherichia coli* in 12.3%; and *Giardia lamblia* in 4.3%.

About 1% of the sample had symptoms of vitamin A deficiency, and about 22% appeared grossly undernourished.

Infectious disease morbidity

About 8% of the plantation workers suffered from systemic or local infection during the 4 weeks preceding the examination. Period prevalence was almost twice as high in anemic men as it was in the non-anemic. For example, the ratio was about 8:5 for influenza and nearly 3:1 for bronchitis. Anemic men also had one-third more cases of diarrhea. Therefore, infectious disease morbidity scores for the 181 in the anemic group (1.63) were significantly higher ($P < 0.01$) than for the 221 in the nonanemic group (1.02). In addition, there was a significant correlation ($P < 0.01$) between morbidity scores and hemoglobin level.

TABLE 1
Distribution of hemoglobin and hematocrit for Indonesian rubber plantation workers. Values for tappers and weeders, preintervention

	Weeders		Tappers	
	n	%	*n*	%
Hemoglobin (g/100 ml)				
Above 14.9	7	5.0	12	4.8
13.0–14.9	76	51.2	122	48.8
11.0–12.9	53	35.8	103	41.2
9.0–10.9	10	6.7	12	4.8
Below 9.0	2	1.3	1	0.4
No. examined	148		250	
Mean		13.0		13.0
SD		1.4		1.4
Hematocrit (%)				
Above 43	15	10.1	28	11.1
38–43	88	59.4	167	66.7
32–37	42	28.6	52	20.7
26–31	1	0.6	4	1.5
Below 26	2	1.3		
No. examined	148		251	
Mean		39.5		40.2
SD		4.1		3.6

HST

The HST scores of tappers and weeders averaged 86% and 71%, respectively. A little over 75% of tappers and 57% of weeders were able to complete the 5-min test.

Differences in performance of anemic and non-anemic workers were highly significant ($P < 0.001$) (Table 3). Thus, anemia, even at the high cut-off level of 13 g/100 ml, affected a worker's ability to perform this test of physical endurance. HST scores were significantly correlated with hemoglobin levels ($r = 0.23$).

Preintervention productivity results

Tappers

Income from rubber tapping, as an index of work output, showed a linear correlation of 0.56 with hemoglobin (Fig. 1). The HST scores of the nonanemic group were 15% greater than those of the anemic group ($P < 0.001$) (Table 3). Mean outputs on a 3-day basis showed a correlation with monthly payments of 0.30 ($P < 0.001$). In addition, there was a significant difference ($P < 0.01$) between the 3-day outputs of anemic and nonanemic tappers (Table 4). Nonanemic tappers collected about 18.7% more latex than anemic tappers did.

Weeders

Even when weeders worked at their normal pace and did not know that their work would be measured, there was a significant difference ($P < 0.015$) between the output of anemic and nonanemic workers (Fig. 2). Anemic workers excavated approximately 20% less earth per day.

TABLE 2
Relation of Stoll count to hemoglobin and hematocrit values in Indonesian rubber plantation workers

Score	Intensity grouping (eggs per mg of feces)	No.	Clinical classification[a]	Hemoglobin		Hematocrit	
0	100	20	Normal	13.2[b]	1.07[c]	40.6[b]	2.9[c]
1	100–699	20	Very light	13.6	1.05	40.8	2.3
2	700–2,599	50	Light	13.3	2.20	39.6	3.1
3	2,600–12,599	66	Moderate	12.9	1.40	38.9	3.0
4	12,600–25,099	6	Heavy	7.9	1.82	26.7	1.4

[a] Classification according to Prof. Sri Oemiyati, Head, Department of Parasitology, University of Indonesia. [b] Mean. [c] SD.

TABLE 3
HST scores of Indonesian rubber plantation workers with hemoglobin scores above and below 13 g/100 ml before intervention

Hemoglobin		Tapper	Weeder	Total
13 g/100 ml	No.	133	82	215
	Mean	80.1	77.9	78.9
	Sd	15.2	14.5	14.8
Below 13 g/100 ml	No.	108	56	164
	Mean	73.4	61.7	68.9
	SD	17.1	20.7	19.7
Difference		6.7[a]	16.2[b]	10.0[b]

[a] Difference significant ($P < 0.01$). [b] Difference significant ($P < 0.001$).

The offer of prizes in 1-hr races almost trebled output for both anemic and nonanemic weeders. The correlation between area weeded during these races and HST scores was 0.2 ($P < 0.1$). The variation among individual weeders was so great, however, that the difference between the two hemoglobin groups was not significant.

There was no evidence that caloric intake of the workers influenced any of the work output measurements.

Postintervention clinical results

Dietary interviews and nutritional status

One of the most significant outcomes of this study was that intake of some foods, mainly edible leaves and fruit, increased sharply during the experimental periods in groups given the 15 rupiah daily incentive for each tablet ingested. These workers stated that they were hungrier because of the "pills" we gave them, but were not able to increase their rice intake because nearly all of their supply came from a fixed allowance set by the Government. The price of rice had also risen a prohibitive 150% throughout the country during that period because of severe shortages in Indonesia occasioned by unfavorable weather. These extra leaves and fruits approximately doubled intakes of available dietary iron from 1.7 to about 5 mg, and of vitamin C from 80 to 130 mg, and added about 200 μg of total folacin per day.

Laboratory findings and clinical status

The iron supplementation significantly raised hemoglobin, hematocrit, serum iron, and transferrin saturation levels of the anemic group when compared to initial values and to the levels of the placebo-treated group (Figs. 3 and 4). Furthermore, a dramatic and highly significant drop ($P < 0.001$) in the TIBC levels of the anemic, iron-treated group also occurred (Fig. 5), indicating that tissue iron stores were raised and replenished by the iron treatment. However, the additional iron (100 mg daily) was insufficient to raise most hemoglobin levels above 14 g/100 ml; a plateau was reached at this level (Fig. 3). In the nonanemic individuals, iron stores were apparently sufficient to maintain hemoglobin levels constant over an extended period (Fig. 4). The non-anemic groups, whether given iron or placebo, showed little change in biochemical indices (Fig. 5). Hemoglobin and hematocrit levels remained remarkably constant over the whole period.

One month postintervention, the hematocrit and hemoglobin levels of the previously anemic placebo-payment group fell rapidly to preintervention levels, whereas the levels of the iron-treated anemic group remained well above the initial level. There was no change in either the hematological values or dietary intake of the untreated subgroup who received no income supplement.

Infectious disease morbidity. Morbidity scores decreased in both anemic groups, but more significantly in that receiving iron and payment ($P < 0.001$) than in that receiving placebo and payment ($P < 0.02$) (Table 5). There was a dramatic decrease in the preva-

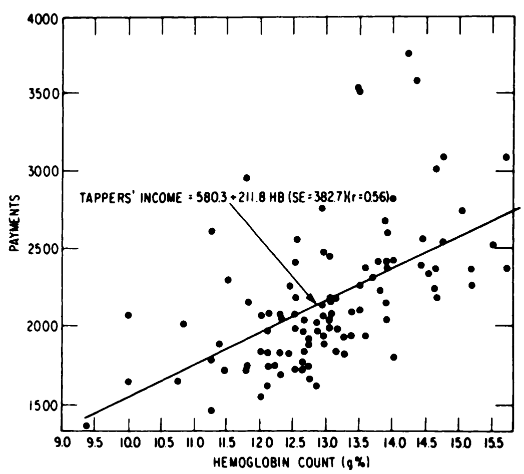

FIG. 1. Hemoglobin versus Tappers' income (preintervention program).

TABLE 4
Difference in mean outputs between anemic and nonanemic rubber tappers in Indonesia

		Before treatment		
		Latex output/man day	Difference in kg latex output/day	Percentage difference between anemic and nonanemic
Anemic		$\bar{X}$:20.94	4.83 kg	
No. = 42		SD: 7.86 kg	($P < 0.01$)	18.7
Nonanemic		$\bar{X}$:25.77 kg		
No. = 35		SD: 9.55 kg		
		After treatment		
		Latex output	Difference in kg latex output/day (iron/placebo)	Percentage difference iron/placebo
		kg		
Anemic	Iron-payment	$\bar{X}$:29.78		
No. = 42	n = 19	SD: 8.47	4.32 kg	14.51
	Placebo-payment	$\bar{X}$:25.46	($P < 0.05$)	
	n = 23	SD:10.88		
Nonanemic	(Combined)	$\bar{X}$:31.40		
No. = 35		SD:12.57		

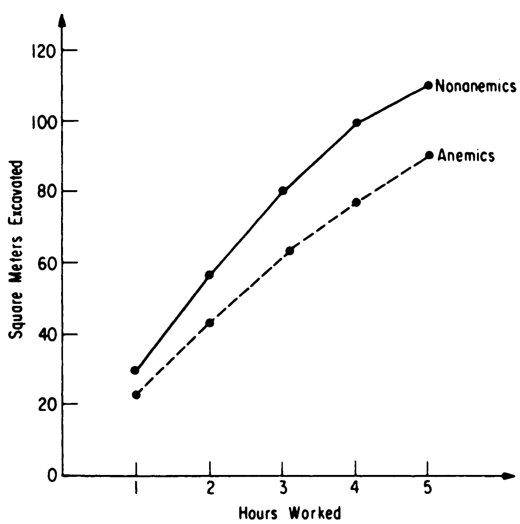

FIG. 2. Daily work output (weeding) for anemic and nonanemic subjects. Note: each *point* or hour represents the cumulative mean for 46 observations in the nonanemic group and 15 observations for the anemic group.

lence of infections in both the anemic and nonanemic iron-payment groups, whereas little change was observed in the placebo-payment groups (Table 6).

HST. There was a rise in HST scores for all except the non-anemic placebo-payment group. As expected, the rise was significantly greatest for the anemic iron-supplemented group ($P < 0.001$), less so for the anemic control group ($P < 0.01$), and least for the nonanemic iron-payment group, where it was barely significant at the 90% level (Table 7). The difference between the post-intervention HST scores of the iron- and placebo-treated groups was significant at $P < 0.05$.

Postintervention productivity results

Tappers

Both the payment-iron and the payment-placebo treated anemic workers showed higher productivity after treatment, but only the iron-payment group reached the level of the nonanemic. The placebo-payment group's productivity was still below that of the latter at the end of the intervention program. The nonanemic tappers did not raise their output significantly with either additional iron or the placebo.

Weeders

There was no significant difference in output between iron-payment and placebo-payment groups after intervention. The total work output of "untreated" weeders was significantly lower ($P < 0.01$) than that of the payment-iron or payment-placebo groups.

Discussion and conclusions

Relationship of clinical and work output results

The results of this intervention study demonstrated an interrelationship among hemo-

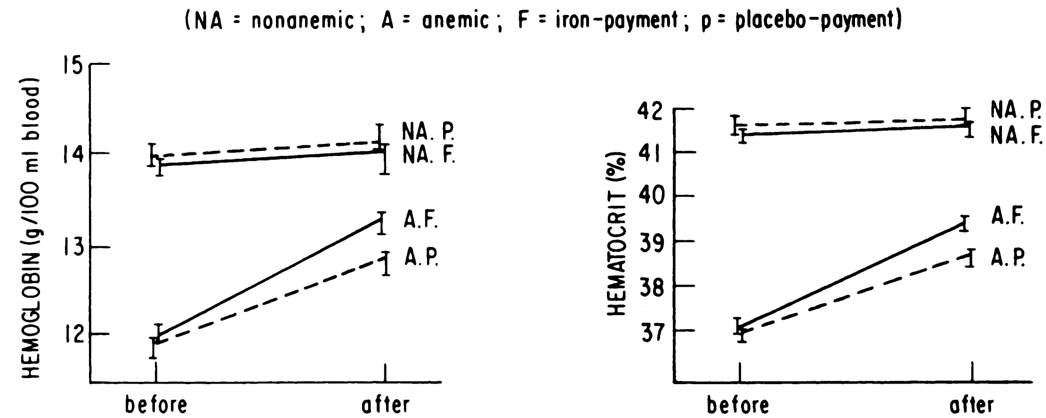

FIG. 3. Mean ± SE hemoglobin and hematocrit values before and after intervention. The differences before and after intervention for the anemic (iron, placebo) groups are highly significant ($P < 0.001$), but are not significant for the nonanemic (iron, placebo) groups. The difference between the iron- and placebo-anemic groups after intervention are significant at $P < 0.085$.

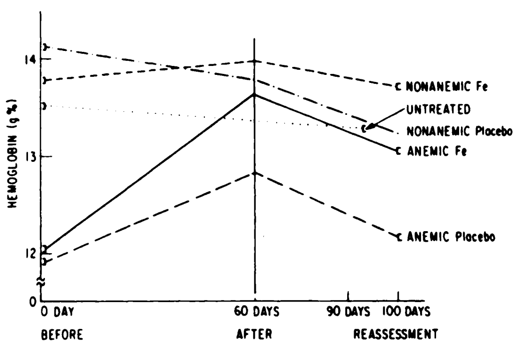

FIG. 4. Mean hemoglobin concentration before and after intervention (± SE$\bar{x}$).

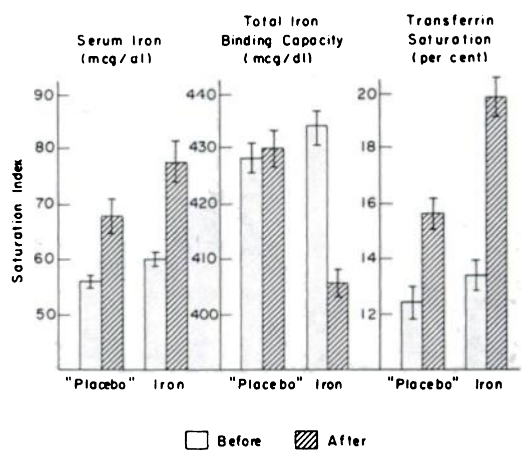

FIG. 5. Differences in plasma, iron, TIBC, and transferrin saturation levels for iron and placebo anemic groups after intervention (means ± SE$\bar{x}$).

globin levels, diet, morbidity from infections, work output, and income. Treatment with ferrous iron and a small incentive payment resulted in greater improvements than the placebo plus payment, although both were effective in anemic subjects. These findings of an effect of anemia on HST performance are similar to those of Viteri and Torun (5).

Because some of the changes in the placebo-payment group were in objective measurements, a true placebo effect is discounted as an explanation of the improvements in this group. Instead, improvements are accounted for by the higher consumption of iron-rich foods made possible by the income supplement paid to study participants. Dietary survey data indicate that a large part of this supplement went for the purchase of food, particularly leaves, which are sources of both iron and vitamin C. The previous vitamin C intake of nonanemic subjects had been almost double that of the anemic subjects, probably an important anemia prevention factor, because sources of vitamin C and iron are often associated, and because vitamin C enhances the absorption of iron (23).

Thirty to 40 days after dextrose and iron administration and incentive payments were stopped, hemoglobin levels were found to have fallen to pretreatment levels in the placebo-payment group, but were maintained in the iron-payment group (Fig. 4). There were no postintervention changes in the hemoglobin levels of the untreated subgroup (Fig. 4).

When workers were separated on the basis of hemoglobin levels, the group that was anemic at the start had a significant rise in hemoglobin levels, while those who were initially non-anemic showed no change. The group of weeders who were anemic cultivated approximately 25% less area than did the non-anemic group (77.39 m^2 compared to 96.98 m^2).

A linear correlation was noted between hemoglobin levels and the monthly payments paid to latex tappers for outputs beyond the daily quota before the study. Nonanemic subjects were found to be consuming more calories, protein, iron, and vitamin C than were anemic subjects at this time.

Subjective observations supported the measured effects of anemia on productivity. For example, workers described by the foreman as "lazy" or "weak" were almost invariably anemic. They had a tendency to assign these weaker workers to the least productive areas, thus reinforcing the poor income/poor nutrition cycle. The anemic workers often complained of feeling tired.

Relationship of work output and economic productivity

Differences between productivity levels of anemic and nonanemic workers amounted to approximately 20% on initial observation. An 8-week intervention program that corrected the iron deficiency of anemic workers increased their work productivity to the level of the nonanemic ones. These increases in productivity were achieved by providing workers with the required iron supplement at a direct cost of only $0.50 (U.S.) per man-year. The $0.03 (U.S.) per day incentive payment,

TABLE 5
Mean morbidity scores for anemic and nonanemic Indonesian rubber plantation workers

Treatment group	No.	Preintervention average	Postintervention average
		$\bar{x}_1 \pm SD$	
Anemic,iron-payment	58	1.38 ± 0.75	0.90 ± 0.72[a]
Anemic, placebo-payment	56	1.29 ± 0.87	0.88 ± 0.81[b]
Nonanemic, iron-payment	59	1.36 ± 0.80	1.25 ± 0.78
Nonanemic, placebo-payment	60	1.43 ± 0.87	1.10 ± 0.73

[a] Difference significant at ($P < 0.001$). [b] Difference significant at ($P < 0.02$).

TABLE 7
Mean HST scores for treatment subgroups, preintervention and postintervention, in Indonesian rubber plantation workers

Treatment group	No.	Mean score preintervention	Mean score postintervention
Anemic, iron-payment	58	69.41	82.20[a]
Anemic, placebo-payment	56	68.39	79.86[b]
Nonanemic, iron-payment	59	79.39	82.98
Nonanemic, placebo-payment	60	781.0	77.48

[a] ($P < 0.001$). [b] ($P < 0.01$).

TABLE 6
Prevalence of infections in iron-payment and placebo-payment subgroups pre- and post-intervention in Indonesian rubber plantation workers

	Anemic				Nonanemic			
	Iron treatment No. = 58		Placebo treatment No. = 56		Iron treatment No. = 59		Placebo treatment No. = 60	
	Intervention		Intervention		Intervention		Intervention	
	Pre-	Post-	Pre-	Post-	Pre-	Post-	Pre-	Post-
Influenza	15.5	5.2	7.1	9.6			3.3	3.3
Common cold	3.4		3.4	1.7	5.1		3.3	1.7
Bronchitis			1.8	1.8				
Tuberculosis			3.4	3.4				
Tonsilitis	3.4	3.4						
Enteritis[a]	6.6	1.8	5.1	3.4	5.1	1.7	4.0	3.2
Gastritis[a]	31.0	20.7	10.4	30.4	28.8	22.0	20.0	25.0
Suspected liver disease								1.7
Conjunctivits	3.4		1.7	5.1			8.5	8.3
Fever			3.4	10.0			5.1	5.1

[a] Enteritis and gastritis denote diarrhea, gas, and pain in lower and upper half of abdomen, respectively.

which, under these circumstances, had nearly the same effect, would amount to $11.00 (U.S.).

In the case of the latex tappers, the resulting benefit/cost ratio is potentially as high as 260:1. This is based on a yearly increase in the amount of latex obtained per hectare of 150 kg (dry weight), at a market value at that time of an extra $44.00 (U.S.) per hectare. The cost of iron administration per hectare (each tapper is assigned 3 hectares) is $0.17 (U.S.) per year. This assumes that additional latex could be sold at existing prices, that there would not be further supply constraints, and that tree production would not be a limiting factor.

If all plantations adopted similar programs and market conditions became less favorable, the price of latex and the resulting benefit/cost ratio could be adversely affected. Even if this were to be the case, a program to correct this nutritional deficiency would still show a very favorable rate of return, because the costs are so low compared to the benefits. Moreover, there are important health benefits that cannot be expressed satisfactorily in financial terms. It has not been possible to calculate the benefit/cost ratio associated with weeding. Weeding the areas around the trees obviously affects latex production, but by how much is not known.

General observations

Diarrheal and respiratory infections were more than twice as common in anemic as in nonanemic males. In addition to nutritional factors (e.g., iron and vitamin C intakes), personal hygiene and soil conditions undoubtedly play an important role in determining whether an individual becomes anemic. In the population studied in Indonesia, 85% suffered from hookworm infestation. If population settlements are dense, the soil moist, and contamination by human defecation is common, it is more likely that hookworm will occur.

When either infection or anemia occurs, poor environmental, economic, and nutritional factors enhance the debilitating effects. Anemic individuals tend to work less, and thus earn less income if paid on a piecework or incentive basis. They can then afford less food. This further aggravates the anemia and increases susceptibility to infection. Increased absenteeism and lowered productivity result, and the worker is trapped in a series of events in which he can improve neither his income, his nutrition, nor his health. In this study, iron treatment abolished the difference between anemic and nonanemic groups in as little as 8 weeks.

The effects of anemia in women and young children on the plantation were not studied. The available literature indicates that in Indonesian women, anemia prevalence approaches the 80% level (24). Given the data from this study on the much higher rate of infection in anemic individuals, and other evidence that anemia predisposes to infection (10, 11), it is not surprising that mortality rates are much higher in women in developing countries. Poorer school performance (25) combined with increased absenteeism due to illness should also be included in any calculation involving the costs (3, 5) and benefits (11, 26) of reducing the incidence of anemia in a particular country.

What, therefore, would be the benefit/cost ratio to a country concerned with reducing high mortality rates in children and reducing the risk of infections, hospital admissions, loss of work days, and poor learning by preventing iron deficiency in women and children? It is clear that a successful, large-scale program to reduce anemia in a population such as in Indonesia would have substantial total benefits beyond work output results. By comparison, the cost of such a program would be small if a suitable delivery system or mechanism could be identified.

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References

1. CIFUENTES, E., AND F. E. VITERI. Physical fitness, iron deficiency and anemia in agricultural laborers of Central America. Federation Proc. 31: 719, 1972.
2. DAVIES, C. T. M., A. C. CHUKWEUMEKA AND J. P. VAN HAAREN. Iron deficiency anemia: Its effect on maximum aerobic power and responses to exercise in African males aged 17–40 years. Clin. Sci. 44: 555, 1973.
3. DAVIES, C. T. M., AND J. P. VAN HAAREN. Effect of treatment on physiological responses to exercise in East African industrial workers with iron deficiency anemia. Brit. J. Industr. Med. 30: 335, 1973.
4. EKBLOM, B., A. N. GOLDBARG AND B. GULLBRING. Response to exercise after blood loss and reinfusion. J. Appl. Physiol. 3 : 175, 1972.
5. VITERI, F. E. AND B. TORUN. Anemia and physical work capacity. Clin. Haematol. 3: 609, 1974.
6. LAYRISSE, M., A. PAZ, N. BLUMENFELD AND M. ROCHE. Hookworm anemia: Iron metabolism and erythrokinetics. Blood 18: 61, 1961.
7. FARID, Z., AND A. MIALE, JR. Treatment of hookworm infection in Egypt with bephenium hydroxynapththoate and the relationship between iron deficiency anemia and intensity of infection. Am. J. Trop. Med. Hyg. 11: 497, 1962.
8. LEE, M. Ferrokinetic study of hookworm anemia. In: Malnutrition and Functions of Blood Cells, edited by N. Shimazono and T. Arakawa. Tokyo, Japan: The National Institute of Nutrition 1973, pp. 295–308.
9. LAYRISSE, M., J. D. COOK, C. MARTINEZ, M. ROCHE, I. N. KUHN, B. R. WALKER AND C. A. FINCH. Food iron absorption; a comparison of vegetable and animal foods. Blood 33: 430, 1969.
10. BAGGS, R. B., AND S. A. MILLER. Nutritional iron deficiency as a determinant of host resistance in the rat. J. Nutr. 103: 1554, 1973.
11. CHANDRA, R. K. Iron and immunocompetence. Nutr. Rev. 34: 129, 1976.
12. CACHMAR, J. F. Hemoglobins, porphyrins, and related compounds. In: Fundamentals of Clinical Chemistry, edited by N. W. Tietz. Philadelphia: W. B. Saunders and Co., 1970, pp. 263–297.
13. BOTHWELL, T. H., AND B. MALLET. The determination of iron plasma or serum. Biochem. J. 59: 599, 1955.
14. RAMSAY, W. M. N. Serum iron determination. Clin. Chem. Acta 2: 214, 1959.
15. WHO/PAHO. Guide to the Southeast Asia Study of Nutritional Anemias. Adapted from the protocols for WHO and PAHO collaborative study on nutritional anemias (PA 247), Geneva, 1964.
16. STOLL, N. R. Investigations on the control of hookworm disease. Am. J. Hyg. 3: 156, 1923.
17. BURKE, M. S. The dietary history as a research tool. J. Am. Dietet. Assoc. 23: 1041, 1947.
18. KLERKS, J. V. The assessment of the Nutritional Status of Indonesian Schoolchildren. Jakarta, Indonesia: Institute of Nutrition, 1953.
19. Departemen Kesehaten. Daftar Komposisi Bahan Makanan (Indonesian Food Composition Table). Indonesia: Direktorat Gizi, 1967.
20. BROUHA, L., A. GRAYBIEL AND C. W. HEATH. The step test. A simple method of measuring physical fitness for hard muscular work in adult men. Rev. Canad. Biol. 2: 86, 1943.
21. DHANUTIRTO, H. Physical Fitness. A Physiological Study with Special Reference to the Use of the Step Test. Ph.D. Thesis, Faculty of Medicine, University of Indonesia, 1970.
22. DHANUTIRTO, H., A. ATMADJA, R. SUTARTO, T. V. DJELANTIK, M. SUHARTO AND W. PANDU. Permeriksaan kesanggupan badan pada para pengemudi. (Examination of physical fitness on pedicab drivers). J. Indonesian Med. Assoc. 16: 584, 1971.
23. CALLENDER, S. T. E. Food iron utilization. In: Iron Deficiency, edited by L. Hallberg, H. G. Harwerth and A. Vanetti. New York: Academic Press, 1970, pp. 75–85.
24. VAN VEEN, M. S. Some ecological considerations of nutrition problems in Java. Ecol. Food Nutr. 1: 31, 1971.
25. POLLITT, E., D. GREENFIELD AND R. LEIBEL. Behavioral effects of iron deficiency among preschool children in Cambridge, Mass. Federation Proc. 37: 487, 1978.
26. GARDNER, G. W., V. R. EDGERTON, R. J. BARNARD AND E. M. BERNAUER. Cardiorespiratory, hematological and physical performance responses of anemic subjects to iron treatment. Am. J. Clin. Nutr. 28: 982, 1975.