ANAEMIA AND WORK OUTPUT

By

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I. INTRODUCTION

I. INTRODUCTION

Increasing population demographic pressure and the demand for more food have put a heavy burden on the world's working population(Hindu, 1983). India has a population of approximately 684 millions according to Manorama (1982). With such a massive ever growing population it should be possible to make a headway in all fields. But malnutrition and ill health seems to be the debilitating factors in meeting with the various demands of our population. The development of natural resources must be geared to the people if the country is to make progress and enable us to be on par with the other developed nations. In other words importance should be given to the proper development of human element which is our greatest resource.

Sadasivam and John (1979) opined that malnutrition leads to wastage of human resources and reduction of this loss would increase the social effectiveness of the population and contribute to economic development.

Ganzin (1976) reports that governments and enterprises in developing countries widely recognise the close relationship between a well fed labour force and high productivity.

Poor nutrition can restrain productivity in terms of output per unit input but restraints may arise as well from increased absenteeism, lowered resistance to disease, lethargy and lack of drive. Poor nutrition also may cripple a nations productivity by more subetle long range mechanisms (LIFE, 1972).

Widespread malnutrition has been cited to reduce productivity by Berg (1973) particularly in the developing countries where the use of heavy physical labour is common. Poor work performance and reduced physical endurance in undernourished subjects have been well documented (Ramamurthy and Dakshyani, 1962; Spurr et al. 1977).

There are indications that absenteeism and incidence of severe respiratory diseases among workers may be reduced by subsidized canteen feeding of nourishing food as stated in LIFE (1972). Absenteeism is damaging among skilled workers who often are in short supply in developing nations. Abs enteeism can result from illness accident or lack of motivation which may be related in turn to inadequate nutrition.

Productivity is related to life span. The economic implications of life span is largely negated by the surplus of labour commonly avilable in developing countries. The productivity of a work force depends on quality as well as on nutrition that tend to lengthen life span which appear inevitablg to upgrade quality.

Lathan (1976) reports that improved nutrition can be shown to have a favourable effect on both per caput income and improved quality of life for people. Viteri et al (1981) state that increased food availability for the working force can result in significant and desirable changes in out of work behaviour, sometimes more meaningful in terms of development and well being than simply greater work output.

Both work capacity and work output are influenced by the nutrient intake and the resulting nutritional status of those who perform work. Childhood malnutrition may also affect the future capacity of individuals for work. It is generally believed that productivity among workers in developing countries is low. This has been attributed at least in part to their poor physique as a consequence of chronic malnutrition. Habitual physical activity was associated with higher work capacity per unit weight, at all ages and all nutritional groups (Sathyanarayana et al. 1978).

Sathyanarayana et al. (1978) point out that the attempts to improve the nutritional status would thus not only be associated with better health but also with economic benefits in terms of increased productivity.

Sathyaranayana et al. (1979) opine that the lack of adequate food for prolonged periods resulted in lethargy and sluggishness and also reduced physical endurance. Viteri (1971 and 1974) conducted physiological studies and indicated that the maximal oxygen uptake as measured by using bicycle ergometer was reduced in malnutrition and resulted in reduction in maximal work capacity.

According to Davidson and Passmore (1975) physical activity is the greatest single factor influencing the calorie needs. Physical activity is combined with an expenditure of energy which in turn is derived from nutrients supplied by the food, people consume.

Physical work capacity can be defined as the potential of an individual to engage in activities involving muscle action. Such activities range from strenuous exercise of short duration to mild exercise of long duration. Individual performance in acute strenuous exercise leading to near exhaustion(maximum exercise) depends mostly on cardio-respiratory reserve, oxygen delivery and metabolic adaptation (such as comes with physical training). A reduction in haemoglobin concentration decreases the oxygen carrying capacity of the blood which may reduce oxygen delivery to the tissues during exercise (WHO, 1975). The more severe the anaemia, the greater the [redacted] in near maximum work [redacted]. Physical [redacted] [redacted] when tissue oxygen demands cannot be met.

Sjolin (1981) points out that in [redacted] [redacted] the [redacted] of iron [redacted] anaemia is often extremely high compared with that in the [redacted] part of the world. It has been [redacted] that there are a total of 260 million anaemic women in the [redacted] world alone. The overall [redacted] of anaemic women is highest in Asia, Oceania, followed in [redacted] order by Africa and Latin America. In developed [redacted] the prevalence of anaemia ranges from 7 to 20 per cent in non pregnant women and upto 35 per cent in pregnant women. Assuming [redacted] that 10 per cent of the non pregnant women and 30 per cent of the pregnant women are anaemic, this would make an [redacted] 31 million bringing the world total (outside China) of anaemic women between 15 and 49 years of age to 291 million (Food and [redacted] Bulletin, 1979).

Iron deficiency is [redacted] the leading deficiency disease and the modern [redacted] of scurvy and pellagra [redacted] to Yates (1979). Iron [redacted] is widely recognized as a major cause of nutritional anaemia both in [redacted] (WHO, 1968 and Cook et al. 1976) and in developed [redacted] such as the United States (AMA Council on Food and [redacted]ttee on iron [redacted], 1968).

Iron deficiency anaemia with its reduction in haemoglobin levels is still a major health problem involving hundreds of millions of people throughout the world as stated by Bengoa (1974).

WHO (1975) points out that "a great deal of ill health sapping energy and productiveness in many countries and causing tragedies in child birth is due to anaemia". Thus it is obvious that urgent steps are needed to prevent and control anaemia.

Nutrition Society of India (1968) analysed some of the factors as the measures for eradication of anaemia namely education to encourage production and consumption of protective foods rich in these nutrients, the enrichment, of foods with iron and distribution of supplements of iron. Giving a diet containing an abundance of foods rich in iron, such as meat, eggs, legumes and some vegetables also increases the haemoglobin content of the blood, but rather slowly. It does not produce immediate results, nor is it feasible for a large population. The therapeutic administration of ferrous sulphate substantially raises the haemoglobin level within a few weeks (Layrisse, 1970).

Supplementation with iron is often the only feasible approach when there is a large deficit to be made up in a relatively short short span of time according to

WHO (1975), INACCG (1977) and Bayer and DeMayer (1979). Finch et al.(1974) report that the most effective way of dealing with a population where the diet is difficult to manipulate is by the use of medicinal iron involving treatment with iron salts.

Thus iron supplementation can be an effective way of combating anaemia and helps in increasing the work output of population groups. This will indirectly help in increasing the gross national product.

Having these points in mind the present study was designed with the following aims:

1. To find out the relationship between nutrition and work output with special reference to iron deficiency among adult men and women doing specific activities and also adolescent boys.

2. To supplement the anaemic volunteers with suitable doses of iron in the form of ferrous sulphate and observe the impact of supplementation.

It is hoped that the results of the study will be of interest to those involved in increasing the work capacity of population groups.

II. REVIEW OF LITERATURE

II. REVIEW OF LITERATURE

The review of literature pertaining to the study on "Anaemia and Work Output" is discussed under the following heads:

1. Importance of increasing productivity
2. Productivity as related to the nutritional status
3. Prevalence of anaemia
4. Anaemia and work output
5. Need for iron supplementation
6. Impact of iron supplementation on work output

1. Importance of increasing productivity:

India is a fast growing country with a population of 684 millions (Manorama, 1982). The human element necessary to fulfill our ideas is abundant. Faris (1966) stated that man needs to build up his strength and knowledge if he is to take the first step from a state of near starvation towards a land of plenty. Gopalan (1974) reported that better nutrition can be the cause besides being the result of socio-economic development. Farris (1966) quoted Thacker and reminded that it is the human resources still largely untapped which constitutes man's real hope for the future. Faris (1966) quotes, U.Thahant who termed it "a call to focus attention on nine - tenths of the iceberg that is submerged. So the human element must take precedence if development is to prove effective.

Governments and enterprises in developing countries have recognised the close relationship between a well fed labour force and a high rate or productivity as stated by Ganzin (1976). Improved production raises the Gross National Product as is pointed out in LIFE (1972) the consequent increase in income would then provide automatically for better nutrition. Sai (1972) reported that every country depends on its working groups for its economic development and it is almost axiomatic that a hungry nation cannot achieve its full potential.

One of the key factors in economic development is the output of the workers, which in turn is influenced by their dietary intake. Sadasivam and John (1979) found out that a well fed worker contributes nearly five times more to production than a malnourished worker.

Aberg (1972) opined that a higher production of food per hectare brings with it a better nutritional status. Improvement of nutritional status is one of the factors improving the conditions of work and as a result, increasing capacity for work(Report on Food and Work, Second International Meeting, 1974).

Efficiency of a well fed worker results in greater earnings, less illness and absenteeism and few accidents and it should also improve the living standards of his dependents, raising both their current food consumption and the future health and production of children as reported by FAO (1976).

The next chapter brings out the relationship between producitivity and nutritional status.

2. Productivity as Related to Nutritional Status:

Nutrition is one of the many inter-related determinents of human performance. Malnutrition leads to wastage of human resources. Reduction of this loss would increase the social effectiveness of the population and contribute to its economic development (Sadasivam and John, 1979). Adequate nutrition is an indispensable base for economic development as stated by Faris (1966). Butterworth and Krumdeik (1970), Correa and Cummins (1971) Call and Longburst (1971), Dema (1971), Yudelman (1971), Berg (1973) and Joy (1973) have focussed the economic implications of a poor nutritional status.

Edmundson (1979) opined that under nutrition may retard work productivity and economic growth of specific social classes in some urban areas and some over populated rural regions of the developing nations.

Although the inter-relationship between food and work efficiency are widely accepted in industrialised countries, they have hitherto received comparitively little attention in many developing countries, according to reports of FAO (1976). FAO (1976) reports that work efficiency is defined as the level at which the worker performs his task and is measured as work produced in a unit of time and the quality of work must meet the accepted standards.

Many developing countries are faced with the problem of how and where to break the vicious circle of undernutrition –– low work efficiency –– low productivity and lack of suitable food.

Severe form of malnutrition and specific vitamin and mineral deficiencies impair work capacity and performance (Viteri et al. 1974 and Dem 1978) to a great extent. According to FAO quoted by Viteri et al (1981) insufficient calories produce results that are socially undesirable.

The FAO (1972) has contended that poor diet reduces the working efficiency by increasing absenteeism, decreasing resistance to disease and causing lethargy and lack of drive. LIFE (1972) reported that lethargy or the inability to maintain a sustained rate of work can result from poor nutrition. Any programme that will provide one meal a day will greatly increase the productivity of the employees.

Sathyaranayana et al. (1979) conducted a study on 96 rural Hyderabad boys aged between 14 and 17 years of age. He opined that impaired work efficiency in undernourished adolescent boys was perhaps the result of current undernutrition than a consequence of early childhood malnutrition. Poor work performance and reduced physical endurance is seen in undernourished subjects as reported by Areskog et al. (1969), Parizkova (1973) and Spurr et al. (1977) who found no reduction in work capacity in under nourished boys and young adults.

Buzina et al. (1979) reported a study on 665 adolescents of 15 - 19 years which indicated that if the nutritional status is adequate short-for-age adolescents perform physical work capacity tests and vital capacity tests as well as their taller peers. When standardized by height physical work capacity, increases with improved nutritional status. Body mass index and relative body weight has a much higher connection to physical working capacity than did body weight.

Chavez et al. (1972) opined that the physical activity of the supplemented children (from early pregnancy to one year) was significantly greater than the non-supplemented one and the difference between the groups increased with age upto the point of being six fold at the age of 2 years. Viteri and Torum (1975) reported that the work intensity and leisure activity were higher in the nutritionally supplemented agricultural workers than in their non-supplemented counter-parts.

Heywood (1974) studied the relationship of certain nutrition factors to the productivity of Jamaican sugarcane cutters. Weight for height was chosen as the measure of nutritional status an index of fatness or thinness and therefore of energy stores. On the Parnassus estate where increase in energy intake(supplementation) was provided in the second half of the season, there was a significant effect of weight for height on productivity. The cutters whose W/H was below 85 per cent cut significantly less cane than those whose W/H was above 95 per cent. There was a significant increase in productivity when supplementation was given.

Belli (1971) has remarked that productivity decreases when the workers do not eat enough. Spurr et al. (1977) indicated that the productivity in 46 chronically under-nourished sugarcane cutters (18-34 years) is affected indirecty by the nutritional status through its influence on the height, fat content and $V_{O_2 max}$.

Satyanarayana et al (1977) reported a study on 57 male industrial workers engaged in the production of detonator fuses. Body weight, height and lean body mass were significantly correlated. Correlation coefficient being as high as 0.72 ($P < 0.001$) with work output. The total daily output was significantly higher ($P < 0.01$) in those with higher body weight and lean body weight. It was also observed that the rate of work increased after the provision of a meal. Viteri (1971) and Spurr et al. (1974) opined that the maximum work capacity is directly related to the body weight or lean body weight. Spurr et al (1974) observed that work output in sugar cane cutters was higher after lunch than before lunch. National Institute of Nutrition (1977) conducted a study on 70 women working in an industry where the work involved soldering of fuse heads. The body weight was significantly related to the productivity. Women whose weights ranged between 50 - 60 kg turned out more work as compared to those with weights 30 - 40 kg, 40 - 50 kg and 60 kg and above.

Satyanarayana et al. (1972) determined the effect of food supplement on the working efficiency of coal miners in the Singareni Collieries. One group received a supplement which provided 500 calories and 11 g protein daily. The other group received no such supplements and served as the control. At the end of 6 months no significant difference was observed between the two groups either in their attendance or per caput production.

Edmundson (1971) opined that peasant farmers in East Java were often as productive as workers with high intake and the relative efficiency of the ten subjects with the lowest energy intake was 80 per cent higher than the high intake group. A selected sample of the same individuals were examined in 1977 and it was found that low levels of energy intake do not necessarily result in low levels of human performance (Edmundson, 1979).

Nutritional surveys in New Guinea by Oomen (1971), Norgan _et al_. (1974) and McAruthur (1977) confirm that low levels of energy intake in the order of 1,700 K.Cal/day or less for adult males and 1,400 K.Cal/day or less for adult females who were physically active and led active lives with relatively minor and infrequent signs of malnutrition.

Apfelbaun _et al_. (1971) carried out a study on 80 subjects who were required to consume a dietary supplement of 1,500 K.Calories above the normal intake and forty one subjects were restricted to a semi-starvation diet of 200 K.Calories. After 15 days of over eating the first group showed an average decrease in work efficiency of 12-29 per cent. The group in the semi-starvation diet showed an average increase in work efficiency 12-17 per cent.

Durnin *et al* (1973) pointed out that individuals in some less developed countries are active and healthy on intakes considered inadequate by current published standards. Reports of small population existing in reasonable physical equilibrium on low energy intakes while maintaining active life style may be found in numerous village nutrition surveys (Schofield *et al*. 1975). Seemingly fit individuals perform heavy work load with much lower energy intake (Norgan *et al*. 1971).

Satyanarayana *et al*. (1978) reports that the major effect of under nutrition on work capacity would thus appear to be mediated through its influence on growth, resulting in young adults with low body weight. Undernourished subjects must be considered to have a handicap since those with low body weights had significantly higher heart rates for a given work load as compared to their heavier counter-parts indicating that they had either low cardio-pulmonary capacity or that the capacity of their muscle to extract oxygen was lowered.

Thus poor nutritional status adversely affects the productivity which in turn retards the economic growth.

3. Prevalence of Anaemia:

WHO (1975) suggested that haemoglobin concentration of less than 13 g/100 ml of blood in adult males and

12 g/100 ml of blood in non-pregnant women of child bearing age is likely to indicate anaemia.

Sauberlich (1976) considered haemoglobin less than 12 g/100 ml deficient in the case of males above 16 years while haemoglobin values less than 10 g/100 ml deficient in case of females above 16 years.

Values below 12 g/100 ml and 11.5 g/100 ml in females are taken as indicative of anaemia as per the norms of Das (1980).

WHO (1975) has reported an overall anaemia prevalence rate of 20 per cent among the world population taken as a whole. It has been estimated that 20 to 60 per cent of the individuals in different countries have sub-clinical or clinical evidence of iron depletion according to Nutrition Reviews (1976). Cook et al. (1980) opined that iron deficiency anaemia affects 10 to 20 per cent of the world's population.

Frey (1978) stated that iron deficiency anaemia is the commonest in all parts of the country. Even in developed countries like Britain, iron deficiency forms 92 per cent of the total anaemias (including all types of anaemia in female population. Baker (1978) pointed out that the incidence of anaemia has been reported to vary from 10 to over 50 per cent and three fourth of the cases have been prescribed to iron deficiency even in developed countries. Das et al (1980) have reported that among college students 15 per cent are anaemic in the United States of America.

In a study in Burma Aung Than-Batu et al (1972) found the prevalence of iron deficiency anaemia to be 5 to 15 per cent among women and 1 to 5 per cent among men (taking the haemoglobin concentration of 11 g/100 ml arbitrarily as the cut off point for anaemia and serum iron less than 50 mg/100 ml as deficiency).

WHO (1974) reported the prevalence of anaemia in India (New Delhi and Vellore) based on the WHO standard of less than 12 g/100 ml for non pregnant women as follows. In New Delhi in a sample of 95 non pregnant women, 64.3 per cent were anaemic. While in Vellore, in a sample of 100 non pregnant women 35 per cent were anaemic. In Vellore the men were 6 per cent anaemic in a total of 99.

Hallberg et al. (1979) stated that 25 to 30 per cent of women in the child bearing age (non-pregnant) were critically ill from iron deficiency anaemia. Sood (1983) reported the prevalence of anaemia among males (15-24 years) to be 6.12 per cent while in females (15-24 years) it was found to be 66.7 per cent during a salt fortification collaborative study 1978 - 1981.

Datta (1982), Rao (1982) and Halder (1982) reported the percentage prevalence of anaemia in the age of 15 - 24 years for males to be 6 per cent in Madras, 42.5 per cent in Hyderabad and 92 per cent in Calcutta.

Thus we see that anaemia ranks as one of the most common maladies affecting mankind all over the world. According to Elwood (1973) iron deficiency is the believed to be an important hazard to health. Greenwood and Richardson (1979) opined that iron deficiency is undoubtedly one of the most serious public health problems during adolescence.

Such a state of prevalence of anamia reflects a poor nutritional status affecting the total work output of the population which is vividly shown in the following chapter on anaemia and work out.

4. Anaemia and Work Out-put:

WHO (1975) reported that physical work capacity can be defined as the potential of an individual to engage in activities involving muscle action. Such activities range from strenuous exercise of short duration to mild exercise of long duration and make use of different mechanisms of physiological adaptation.

Individual performance in acute strenuous exercise leading to near exhaustion depends mostly on cardio respiratory reserve, oxygen delivery and metabolic adaptation.

Physical endurance differs from productivity in that the former refers to the ability to perform certain physical tests under an artificial environment and the latter refers to the output of physical work in a real situation as stated by Soekirman (1974).

FAO (1977) classifies that iron deficiency anaemia occurs when losses of iron from the body are not balanced by absorption of sufficient iron to compensate for both normal and abnormal losses.

Iron deficiency anaemia affects the physical work capacity by reducing the availability of oxygen to the tissues which in turn affects the cardiac output and the heart, eventually leading to death in severe cases. Basta (1977) and FAO (1977) reveal that World Bank has identified iron deficiency anaemia among the possible factors limitting work output and physical capacity of male agricultural and road construction workers under tropical conditions.

Edgerton *et al* (1979) conducted a study on the effects of iron deficiency on worker productivity in a tea plantation estate in Kandy area of Sri Lanka. The quantity of tea picked/day was studied before and after iron supplementation. Afeer one month's treatment, significantly more tea was picked when the haemoglobin concentration was increased by iron supplementation (200 mg ferrous sulphate) than when it iwas not. The degree of improvement was greater in the more anaemic subjects.

The economic implications of increased work productivity with iron treatment are evident, particularly in developing countries. These results also provide strong evidence for the clinical impression that people with iron deficiency anaemia suffer from tiredness and weakness (Edgerton *et al*. 1979).

A study was carried out in Sweden (1979) to find the effectof iron supplementation on the working capacity. Healthy women in the age range of 58 to 71 years were chosen for the study. Half of the women were given iron supplements twice daily for a period of three months and a half of were given placebo. The average work performance on an exercise bicycle was improved in both groups. The improvement was about four times greater in the supplemented group.

Gardner *et al* (1977) examined the performance of 75 women plantation workers in Sri Lanka on a treadmill. The women were grouped in a step ladder fashion, according to their haemoglobin levels in their blood from 6 g/100 ml (serious anaemia) to 13 g/100 ml. With each step, down the ladder, the work performance dropped. Subjects with haemoglobin concentration 11.0 and 11.9 g/100 ml showed approximately a 20 per cent decrease in the work tolerance when compared to subjects with haemoglobin concentration greater than 13 g/100 ml.

Gardner *et al* (1975) conducted a study in Venezuela on 29 adult iron defecient subjects with haemoglobin levels 4.0 to 12.00 g/100 ml. Haemoglobin levels for the iron treated groups after 83 days improved from 7.7 to 12.4 g for the women and from 7.1 to 14.0 g for the men. The results support the concept that performance requiring high oxygen delivery is significantly affected by haemoglobin levels since 4 of the 29 anaemic subjects were unable to complete the 5 minute stepping task.

Lathan *et al* (1979) conducted work output studies on 281 road construction workers in the highland district of Nyeri and the coastal districtof Kwale, Kenya. Low body weight for height was strongly associated with lower productivity and over time, low haemoglobin was associated with low productivity.

The highland population was given a drink fortified with sugar (supplying 700 calories of energy daily) since those workers were on the average around 80 per cent below the recommended weight for height norms, while the other half received the same drink containing saccharine. After 4 weeks the outputs were measured. It was found that those given energy drink increased in weight as compared to those given saccharine but no detectable difference between the two groups in terms of work output.

The World Bank undertook a study with the All India Institute of Medical Sciences (AIIMS), in New Delhi, Northern India during (1974). A survey of about 200 road workers in northern Uttar Pradesh revealed that the outputs of one of the two populations studied was correlated with the haemoglobin levels. Output was measured as the amount of earth hauled and dumped over a fixed distance. In both the population there was a close relationship between output and dietary iron and folate levels.

Basta and Churchill (1974) carried out a study on male construction and plantation workers in Indonesia. Iron deficiency anaemia was prevalent among plantation workers and on administration of Harward Step Test, an inverse relationship was established between anaemia and physical work capacity. To test the effectof supplementation

(100 mg of elemental iron), two typical plantation jobs were chosen. Tappers and weeders were split into anaemic and non anaemic groups. Iron pills and placebo were administered on a double blind basis to both groups. Anaemic tapper output was 19 per cent below non anaemic output. Weeder anaemic output was 20 per cent below non anaemic output. After supplementation the output of both tapper groups was equal. The placebo anaemic group experienced increased output but was still 15 per cent below the non-anaemic and supplementation groups. The supplementation or placebo did not increase the work output in the non-anaemic tappers.

In weeders, no difference was discovered between the output of supplemented anaemic weeders and placebo anaemic weeders. Anaemic men who received supplementation demonstrated a dramatic increase in serum iron transferrin saturation and TIBC levels. Anaemic groups receiving placebo showed no change.

Finch et al (1977) reported that fatigue and limited ability to perform muscular work have long been recognized as accompaniments of iron deficiency. A low oxygen carrying capacity of the anaemic blood has been assumed to be the major reason for the low work capacity.

Viteri and Torum (1975) reported that in sugarcane cutters there was a direct relationship between haemoglobin concentration (or) packed cell volume and score on the Harward Step Test which assures cardio respiratory reserve with near maximum exercise.

According to Gopalan (1975) the work output depends on physical efficiency and anaemia profoundly affects the work performance. Since to perform energy demanding tasks, blood must be able to transport oxygen at a rate and level required by the effort, which in turn depends on circulating levels of haemoglobin.

Ohira (1979) opined that haemoglobin and maximal work time increased significantly within four days after iron treatment and continued to increase upto sixteen days in six anaemic men and fourteen anaemic women after a total dosage infusion of iron dextran by vein (30 - 50 ml).

Karyadi and Basta (1973) carried out a study in Indonesia Nutrition Research Institute among road construction workers in Java. The workers belonged to 18 - 39 years. About 41 per cent of the workers were iron deficient (WHO haemoglobin standard) and out of them about 10 per cent were also thought to be suffering from folate deficiency. The results showed that moderate to severe anaemia (11.1 g/100 ml) present in 33 per cent of samples was closely associated with poor performance in Harward Step Test (HST).

Another study by Basta et al (1974) was undertaken in West Java with the Indonesian Nutrition Research Institute. The daily work output of about 600 rubber plantation workers was measured. Two types of work was measured namely tapping, and weeding. In so far as the weeds were concerned during their five hour work day the anaemic workers cleared an area about 20 per cent less than the non-anaemic workers. The intervention programme was carried out for 6 weeks. After 6 weeks, work output measurements showed that the previously anaemic tappers were producing just as much latex as non anaemic ones. The haemoglobin levels of both groups were then similar.

Basta et al (1979) conducted another study on rubber plantation workers in West Java Indonesia. Forty five per cent were anaemic as judged by haemoglobin below 13 g/100 ml. Haemoglobin values and Harward Step Test (HST) performance for tappers and weeders were significantly correlated. The rubber tappers were paid by their work output, their earnings were correlated with haemoglobin values. Morbidity and haemoglobin values were also correlated. Treatment with 100 mg elemental iron for 60 days significantly improved haematological status of the anaemic men and their Harward Step Test performance, work output and morbidity. Treatment with placebo groups, received a daily incentive payment of 15 rupiahs equivalent to 5 to 7 per cent minimum daily wages. The sum spent largely on food, resulted in added intakes of 3 to 5 mg available iron and 50 mg vitamin C. This is believed to explain a significantbut smaller improvement in haemoglobin, Harward Step Testperformance, work output and morbidity in the anaemic placebo group. In an untreated subsample to whom no payment was given no change in haemoglobin, haematocrit, work performance, Harward Step Test score or disease morbidity occured. After income supplementation was stopped haemoglobin and haemotocrit values and related changes reverted to initial values within 30 days in the placebo group but did not change in the iron related group. The cost of iron supplementation was small compared with the conomic benefits of increased productivity and lowered morbidity.

WHO (1975) stated that severe anaemia impairs the maximum work capacity. Basta (1977) reported that iron deficiency anaemia impairs the work output and energy expenditure of an individual.

Since iron deficiency anaemia is highly prevalent among adults, many of whom are engaged in agricultural or other physical work, this effect of anaemia on work performance may be of great significance on the economy and productivity.

Cardiorespiratory function:

Anderson and Barkve (1970) have reported that iron deficiency anaemia impairs the working capacity of individuals by placing an excessively increased load on their cardio respiratory function. They felt that higher ventilation equivalents (Ventilation/oxygen uptake) found in anaemic subjects was due to the lower levels of haemoglobin.

Davie et al (1973) found no respiratory changes but significant cardio-vascular changes in 17 subjects whose haemoglobin ranged from 6.0 -9.2 g/100 ml blood. Anderson and Barkve (1970) reported a higher exercise and recovery heart rates for anaemic subjects. Delano et al (1972) opined a high incidence of S-T segment ECG changes in anaemic subjects.

5. Need for Iron Supplementation:

Iron is an essential nutrient and a common substance seen all round us in every day life. Sharma (1973) reports that iron deficiency is the cause of widespread illhealth, inefficiency and unhappiness.

WHO (1975) has pointed out that "a great deal of illhealth sapping energy and productiveness in many countries and causing tragedies in child birth is due to anaemia so immediate and urgent steps are needed to prevent and control anaemia.

The education of protective foods rich in iron is the best way. Nutrition Education is essential for combating it (Devadas, 1973, 1977 and Burgess and Burgess, 1976). The enrichment of foods with iron is a potential method for preventing anaemia. Studies on it are few so fortification of foodstuffs with iron cannot form the basis of a public health programme for the prevention of anaemia at this stage. Fortification appears better but is a more difficult, long term solution to the problem.

According to NIN (1968), WHO (1975), INACG (1977) and Baker and DeMayer (1979) the most obvious and feasible approach to the prevention and control of anaemia in a large population, to be made up in a short span of time is through the supplementation of iron.

NIN (1968) and Krause and Mahan (1979) report that trials in several centers have shown that iron supplementation to anaemic people can effectively control the problem of iron deficiency. The prophylactic dose of iron should be

60 mg of elemental iron per day. The actual compound to be used should be either ferrous sulphate or ferrous fumarate.

The vast majority will improve with simple dietary supplementation and additional iron preparation. Ferrous sulphate is quite effective and the rise in haemoglobin level is directly proportional to the amount of elemental iron administered upto a dose of 200 mg/day. Any severe anaemia takes about 6 - 8 weeks on dietary supplementation and medication to reach normal as pointed out by Das (1980).

NIN (1978) undertook a study on 5 human volunteers and 6 monkeys. The iron tablet used in the nutritional anaemia prophylaxis programme, containing 60 mg of iron as ferrous sulphate and 500 mg folic acid was investigated. After the experiment it was concluded that as by eight hours after dosing serum iron values had returned to almost basal levels in monkeys. In human subjects however the basal values were reached only after 12 hours of dosing. This experiment also gives an index for bio-availability of iron tablets as represented by the rise of serum iron to the peak value.

Aungthan Batu et al (1972) reported that after 6 weeks of iron therapy given orally as ferrous sulphate containing 120 mg elemental non daily the serum iron values less than 50 μg/100 ml had a significant increase of 2 gm/100 ml in mean haemoglobin concentration in contrast to 0.2 g/100 ml in those given pacebo.

The treatment of iron deficiency by supplementation is a easy and quick and effective step. There is a wide choice of preparation varying greatly in price but the least expensive such as ferrous sulphate, ferrous gluconate are entirely satisfactory. INACG (1981) reports that gastro-intestinal side effects represent the main limiting factor in oral iron therapy. These often disappear if treatment is continued or may be tolerable if dose is reduced.

There is evidence to show that iron in medicinal form is better absorbed and hence iron supplementation is useful in eradicating anaemia.

6. <u>Impactof Iron Supplementation on Work Output:</u>

Gopalan (1975) reported that more severe the anaemia the greater is the reduction in near maximum work performance.

FAO (1977) reveals that the World Bank has identified iron deficiency anaemia among the possible factors limiting work output and physical capacity of of agricultural and road construction workers under tropical conditions. To make best use of the readily available human resources, supplementation is an effective step in combating anaemia and increasing productivity.

Iron supplementation has an important beneficial impact on the work output as reported by Edgerton et al (1979), Lathan et al (1979), Basta and Churchill (1978) and Basta et al (1974).

Gardner et al (1975) opined that iron supplementation has an improved effect on the work performance.

The cost of iron supplementation is small compared with economic benefits of increased productivity and lowered morbidity as stated by Baste et al in (1979).

III. EXPERIMENTAL PROCEDURE

III. EXPERIMENTAL PROCEDURE

The experimental procedure pertaining to the study on "Anaemia and Work Output" is dealt with under the following headings:

1. Selection of the area
2. Selection of the volunteers
3. Assessing the nutritional status of the volunteers
    a) Conducting food weighment survey
    b) Recording heights and weights of the volunteers
    c) Carrying out biochemical estimations
4. Recording pulse rate and blood pressure
5. Estimating the energy expenditure
6. Quantifying work output for specific activities
7. Estimating physical work capacity with an ergometer
8. Supplementation with iron

and 9. Evaluating work output after supplementation

1. Selection of the Area:

Two different places were chosen as the venue for the research work. The first one was an industry namely G.D.Naidu Industry and the second one was Sri Ramakrishna

School of Agriculture in Perianaickenpalayam. These two places were chosen as it was easy to reach the places and whole-hearted cooperation was extended by the managements and authorities in both the places. The workers in the G.D.Naidu Industry and the students in the Sri Ramakrishna School of Agriculture, promised their cooperation for the study.

2. Selection of the Volunteers:

It was decided to choose a set of adolescent boys and a set of working adult men and women as volunteers for the study, because there is a need to find out the work output of adult men and women and also adolescent boys who form a big proportion in the working population.

Accordingly 19 adult women and 18 adult men who were anaemic were chosen for the study and 4 men whose haemoglobin levels were satisfactory served as controls from the G.D.Naidu Industry. There was no control group available for the women.

Thirty eight anaemic adolescent boys were available for the study from Sri Ramakrishna School of Agriculture and 16 boys who were not anaemic were chosen as controls.

3. Assessing the Nutritional Status of the Volunteers:

a) Conducting food weighment survey:

Food weighment survey is supposed to be most accurate among the various methods of diet surveys and hence it was proposed to conduct food weighment survey on a subsample of 30 volunteers 8 adult men, 10 adult women and 7 from adolescent boys all of whom were anaemic. Two adult men, and three adolescent boys from non-anaemic group were also chosen for weighment survey. Tasker et al (1968) points out that a 3 day weighment survey would be sufficient, as the dietary variation in day to day life is not large.

All the raw food items were weighed before cooking. Then the total cooked weight of the food was recorded. After this the volunteers were requested to consume the food. As soon as the eating was over, the quantity of food left unconsumed was weighed and this was subetracted from the total cooked weight of the food. From the above data, the quantity of cooked food consumed by the individual was obtained.

The raw ingredients used were computed from the cooked food consumed. From this figure, the nutrients available from the diet per day was calculated using the "Nutritive Value of Indian Foods"(Gopalan et al. 1982).

b) Recording heights and weights of the volunteers:

Heights and weights were recorded for all the volunteers and the volunteers were selected in such a manner that the differences in height and weight between them was not statistically significant.

The height was measured using a fibre glass tape fixed to the wall. The volunteers were made to stand errect and upright on a firm level floor bardfooted against the tape with arms hanging freely at the sides. A wooden scale was placed gently on the head, perpendicular to the wall and the height was measured from the tape nearest to 0.1 cm.

The weights were measured with the help of a spring balance. Before weighing the balance was checked for its accuracy with the help of standard weights. The weighing scale could read nearest to 250 grams. Spring balance was used as transport of heavy lever type balance was difficult. Gurney (1969) points out that a spring balance is adequate to measure the weights, provided the balance is checked frequently for accuracy.

c) Carrying out biochemical estimations:

Biochemical estimations are accurate means of assessing the nutritional status of the population groups.

i) <u>Estimation of serum iron:</u>

Four to five ml of venous blood was collected from all the volunteers participating in the study and the serum was separated. Serum iron was measured by the Dipyridyl method of Varley (1969). The details for the estimation of serum iron are given in Appendix (1).

ii) <u>Estimation of haemoglobin:</u>

A finger prick was made and 0.02 ml of blood was collected with the help of a micro pipette. The blood was blown out into a filter paper and stored after labelling. The concentration of haemoglobin was most reliably measured after accurate dilution of the blood sample in a solution that converts haemoglobin to cyanmet haemoglobin which is then quantified spectrophotometrically using the method of Crosby et al (1954). The values thus arrived at were compared with those of Sauberlich (1976) and all those below the range of 12.0 g/100 ml were termed anaemic in case of men and adolescent boys and all those less than 10.0 g/100 ml were termed anaemic incase of adult women. The procedure for the estimation of haemoglobin is given in Appendix (2)

4. <u>Recording the Pulse Rate and Blood Pressure:</u>

The pulse rate and blood pressure were recorded before and after the different activities.

The pulse rate was recorded for the various activities before and after the supplementation to see the effects of activity on pulse rate.

For recording the blood pressure the subjects were made to lie in a comfortable position and the blood pressure was recorded using a sphygmomanometer (sphygmos = pulse) by auscultatory method.

In the indirect or clinical method (first suggested by Vierodt in 1855) the height of a column of mercury - or other force - required to suppress the pulsations in an artery is employed as a measure of the pressure in the blood in the artery. The instrument consists of an inflated cloth-covered rubber bag which fits snugly around the upper arm which is held in position by wrapping an extension of the cloth covering over the bag and about the arm like a bandage. The bag communicates with a mercury manometer and can be inflated by a pressure bulb. On the tube leading from the bulb to the bag there is a needle valve which can be opened gradually to allow air to escape and the pressure in the bag to fall.

To measure the pressure the cuff is wrapped tightly around the volunteers arm in the region of the brachial artery. Air is pumped into the cuff until the air pressure is great enough to compress the artery so that no pulse is heard. The stethoscope is used to listen to the pulse of the brachial artery at the elbow. Then the valve is opened slightly so that the pressure in the cuff beings to fall. Soon a distinct sound is heard as blood spurts into the artery once again. The pressure at that instant is read as the sytolic pressure. The sound gets louder and then changes in quality, and finally becomes inaudible. Pressure at the time the sound is no longer audible is read as the diastolic pressure.

The blood pressure was recorded for all the activities before and after supplementation with ferrous sulphate tablets.

5. Estimating the Energy Expenditure:

The energy expenditure of the volunteers during activity was recorded using an apparatus called Kofranyi - Michaelis respirometer. The apparatus is made of rubber and usualy of 100 litres capacity. It is light weight portable respirometer which can measure directly the volume of expired air and simultaneously divert a small fraction into a foot ball bladder for subsequent analysis. The instrument can be worn at the back like a haversack. The expired gas in the rubber bladder was analysed for its oxygen content. The oxygen consumption was converted into kilo-calories using the formula given by Bratton (1959) which is given below:

$$\frac{\text{Cubic centimeters of } O_2\text{/minute}}{1{,}000} \times 4.86$$

Details for the conversion of respirometer data to oxygen units is given in Appendix (3).

The major equipment used for the study was

1) Kofranyi Michaelis Respirometer

2) Beckman oxygen analyser

Kofranyi Michaelis Respirometer:- It is a simplified and compact unit which is fairly small 20 x 27 x 11 cm and weighs 3 kg. It is delicate and portable.

The parts of the respirometer are Rubber Bladder, Nose clip, Rubber tubing, Mouth piece and Valve.

There are exit and entry parts one on each side of the respirometer. The operation of the Kofranyi Michaelis Respirometer involved the following steps.

1. Saturating the rubber bladder with the expired air for two to three hours in order to fill in the air spaces of the bladder, thus preventing diffusion of air.

2. Placing the respirometer on the back of the subject.

3. Attaching the rubber bladder after emptying to the exit part of the respirometer with a screw clip.

4. Fixing the nose clip and mouth piece

5. Turning the tap on the respirometer (right hand side of the subject) to the position required to extract either 0.6 or 0.3 per cent of the total air expired passing through the meter.

6. Noting down the reading on the meter scale of the respirometer.

7. Turning the tap on the respirometer (left hand side of the subject) to vertical position.

8. Noting down the time, room temperature and the barometric pressure.

9. Turning the tap to the horizontal position at the end of each test period.

10. Noting down the reading on meter dial of the respirometer.

11. Removing the nose clip and mouth piece.

12. Removing the rubber bladder after closing it tight with the screw clip.

13. Analysing the gas content in the rubber bladder

and 14. Cleaning the mouth piece and the nose clip.

Precautions:- Some of the precautions listed below are stated by Consolazia (1971) and followed in the present study.

1. Prior to the collection of expired air, it was tested for leaks through the nose clamp of expired air. The respirometer valve was checked for leaks.

2. The aliquot bags were checked for leaks. The sample of expired air was removed with the syringe as soon as possible to minimise errors introduced by diffusion of gases through the rubber bladder. The aliquot bladder was always stored full of expired air in order to saturate the rubber with carbon dioxide. Prior to use, the bladder must be evacuated with a vacum pump and close off with a pinch clip.

3. The equipment was operated for a few minutes prior to the beginning of the measurement.

4. Whenever possible, the expired gas was analysed directly from the bag, and was

certain that the expired air had reached equilibrium at room temperature prior to analysis.

Beckman Oxygen analyser:- The Beckman oxygen analyser was used for determining the percentage of oxygen present in the expired air.

The following are the steps:

1. Connecting the rubber bladder to the sampling tube after removing the protective rubber bulb.

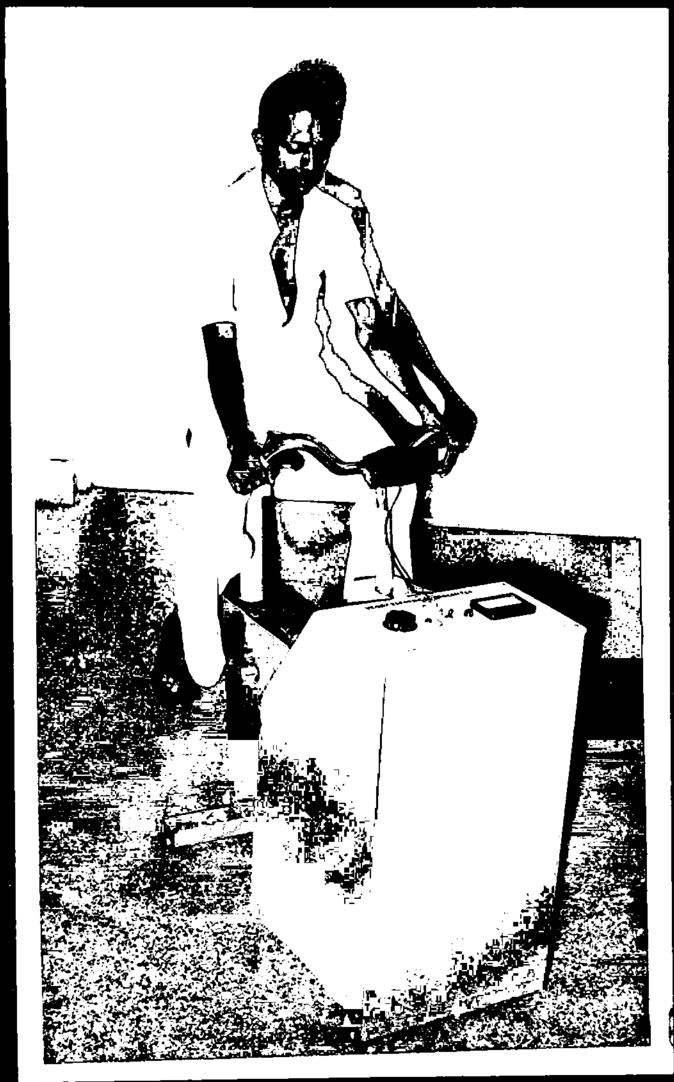
2. Loosening the screw clip on the rubber bladder.

3. Pressing and releasing the respirometer bulb till all the air in the bladder enters the analyzer.

4. Noting down the percentage reading on the meter scale of the analyser at once.

Other accessories are stop-watch, metronome, thermometer and barometer. A stop-watch was used to note the time taken for all the activities. A metronome controlled the speed of the subjects while performing the activities. A thermometer graded in centigrade and a barometer graduated in millimeters were used to record the room termperature and atmospheric pressure.

Figure A A VOLUNTEER ON AN ELECTRICAL ERGOMETER



The energy expenditure incurred during various activities by the anaemic group was compared with that of the non-anaemic group.

6. <u>Quantifying work Output for Specific Activities:</u>

The activity performed by six men and nine women was profile milling and milling of slots respectively. The machine used was a production milling, manually operated with manual feeding in the standing position.

In profile milling the piece was clamped in the collet then the flat surfaces were milled to a radius of 4 R one by one, after indexing (rotating to 180°) the piece was then removed from the collet holder after loosening the collet. The milling of slots involved milling two slots in a single operation on the face of a gear blank.

The other activities performed by a set of sixteen men in the same industry was match lapping and rough lapping. There were six men in each category and two controls in each. The job required the worker to stand at a place and manually feed the electrically operated motor.

Match lapping involved fixing the needle and barrel in the collet, then removing the barrel, applying the paste on the neddle and then lapping the barrel and finally removing the piece from the collet. Rough lapping required fitting the lapping bush on the mentel applying the paste and then lapping till the bore in barrel was 1 µ.

Lapping was performed by ten women, but here the nozzle used was perkins. The activity required the worker to sit at a place and carry out the following operations fixing the tone in the jaws, applying the paste in a 60° angle and lapping the bottom of the seat (nozzle).

The work output in an eight hour shift was measured in terms of number of pieces milled or lapped and could therefore be precisely quantified. The workers were given an incentive pay according to the number of pieces milled or lapped after fulfilling the minimum output to earn their basic wages.

In case of the all the adolescent boys the length of the single furrow made for sugar cane plantation in a specified time was taken as the activity. The work output for different activities was observed before and after supplementation.

7. **Estimating the Physical Work Capacity with an Ergometer:**

The method used was that developed by Sjostrand (1947) which basically involved measurement of heart rate at known levels of generalised work as performed on a bicycle ergometer. An ergometer (ergo = work, meter = measure) is an instrument in which the amounts of mechanical work per unit of time are registered. Heart rates of the subjects were monitored while they were cycling at a speed of 60 revolutions per minute against known amounts of resistance in the sitting position on a Venky Electrical Ergometer. The subjects were encouraged to pedal upto complete exhaustion. In the present study the ergometer was used to study the physical work capacity of the volunteers. Figure A shows a volunteer working on the ergometer.

8. **Supplementation with Iron:**

All the 19 anaemic women, 18 anaemic men and 38 anaemic adolescents were supplemented with elemental iron of 60 mg of ferrous sulphate per day for 120 days. The non-anaemic volunteers were given a placebo tablet to avoid differenciation. A supervisor distributed the tablets every day after lunch break.

9. Evaluating the Impact of Supplementation:

The haemoglobin and serum iron levels were estimated after iron supplementation and was compared with the initial values. The energy expenditure in milling, lapping and in making a furrow was found and compared with the earlier values. Similarly the differences in work output in the number of pieces milled and lapped was determined. Also the physical work capacity with an ergometer was measured and compared with the earlier values.

IV. RESULTS AND DISCUSSION

IV. RESULTS AND DISCUSSION

The results and discussions pertaining to this study on "Anaemia and Work Output" is discussed under the following headings:

1. Nutritional status of the volunteers
   a) Mean food and nutrient intake of the volunteers
   b) Mean heights and weights of the volunteers
   c) Mean serum iron levels of the volunteers
   d) Mean haemoglobin levels of the volunteers
2. Pulse rate and blood pressure of the volunteers
3. Energy expenditure of the volunteers as estimated with Kofranyi Michaelis respirometer
4. Work output in carrying out the specific activities
5. Physical work capacity with an electrical ergometer
6. Impact of iron supplementation on the volunteers.

1. Nutritional Status of the Volunteers:

a) Mean food and nutrient intake of the volunteers:

Table I brings out the mean food intake of the volunteers participating in the study.

TABLE I

MEAN FOOD INTAKE OF THE VOLUNTEERS

Food stuffs (g)	Men			Women		Adolescent boys		
	Anaemic Vegetarian	Non Anaemic Vegetarian	ICMR Recommended Allowances 1982	Anaemic Non Vegetarian	ICMR Recommended Allowances 1982	Anaemic Vegetarian	Non Anaemic Vegetarian	ICMR Recommended Allowances 1982
Cereals	378	375	475	274	350	436	574	450
Pulses	39	35	80	40	55	39	35	70
Green leafy vegetables	14	25	125	6	125	0	14	100
Other vegetables	54	30	75	48	75	44	85	75
Roots and Tubers	34	13	100	52	75	48	45	100
Fruits	28	25	300	36	30	18	62	30
Milk and Milk Products	225	200	200	284	100	180	242	250
Fats and Oilseeds	22	20	40	22	40	18	20	45
Meat and Fish	—	—	—	·3	30	—	—	—
Egg	—	—	—	8	30	—	—	—
Sugar and jaggery	23	28	40	26	30	24	15	40
Nuts	22	18	—	21	—	19	44	50

The food intake of the adult males both anaemic and non-anaemics was adequate with respect to only milk and milk products. The intake of all other foods were inadequate. However the intake of green leafy vegetables and jaggery were higher among the non-anaemic males than among the anaemic males.

The mean food intake of the anaemic women was inadequate with respect to cereals, pulses, green leafy vegetables, other vegetables, roots and tubers, fats, meats, fish, egg, sugar and jaggery. It was adequate only with respect to fruits and milk and milk products.

The mean food intake of the anaemic adolescent boys was inadequate with respect to all the foods and green leafy vegetables were totally missing. The mean food intake of the non-anaemic boys was adequate with respect to cereals and fruits. They had consumed some amount of greens at least.

Mean nutrient intake of the volunteers:

Table II presents the mean nutrient intake of the volunteers.

TABLE II

MEAN NUTRIENT INTAKE OF THE VOLUNTEERS

Nutrients	Men			Women		Adolescent boys		
	Anaemic	Non-Anaemic	ICMR Recommend-allowances 1982	Anaemic	ICMR Recommended allowances 1982	Anaemic	Non Anaemic	ICMR Recommended allowances 1982
Protein (g)	49	54	55	44	45	44	59	60
Energy (K.Cals)	2130	2531	2800	2000	2200	2411	2684	3000
Calcium (mg)	352	560	400–500	571	400–500	330	419	400–500
Iron (mg)	21	28	20	16	30	20	25	25
Retinol (µg)	719	528	750	66	750	215.75	370	750
Thiamine (mg)	0.8	2.02	1.4	1.26	1.1	1.08	1.08	1.5
Riboflavin (mg)	0.71	0.76	1.5	1.10	1.2	0.64	0.73	1.7
Vitamin C (mg)	40.02	48.72	50	44.95	50	24.13	52.09	50

The nutrient intake of the anaemic men was inadequate with reference to all the nutrients when compared with the recommended dietary allowances. However the difference was marginal. The nutrient intake of non anaemic men was better and their intake with reference to calcium, iron and thiamine was even above, the recommended dietary allowances.

Calculation of the mean nutrient intake revealed that the intake of energy, iron and retinol was inadequate for anaemic women while the intake of protein, riboflavin [illegible] and vitamin C was only slightly inadequate when compared with the recommended allowances.

In case of anaemic adolescent boys the intake of protein, energy, calcium, retinol, iron and vitamin C, fell below the recommended allowances. The intake of non-anaemics was much better with reference to protein, calcium and iron and tallied well with the recommended allowances.

These results on food and nutrient intake reveal that the intake of iron rich foods is low among anaemics and the same is better among non-anaemics among the different groups studied. This low intake of iron rich foods is reflected in the nutrient intake where the iron obtained from the diets of anaemics are lower than the values recorded by the non-anaemics.

Individual data pertaining to the food and nutrient intake is given in the Appendix 4.

b) Mean heights and weights of the volunteers:

Table IIIhighlights the mean height and weight of the volunteers.

TABLE III

MEAN HEIGHT AND WEIGHT OF THE VOLUNTEERS

Groups	Number	Mean Height in cm	't' value	Mean Weight in kg	't' Value
Men:					
Anaemic	18	165.6	0.88	48.3	0.59
Non Anaemic	4	166.2		50	
Women:					
Anaemic	19	151.1		44	
Non Anaemic	—	—		—	—
Adolescent Boys:					
Anaemic	38	165.6	0.67	47.0	0.775
Non Anaemic	16	166.8		47.8	

The volunteers for the present study were so chosen that the age group in each category was comparable. The male volunteers were in the age group of 24 - 25 years.

The mean height of the anaemic men was 165.6 cm against 166.2 cm recorded by the non-anaemic men. In case of women volunteers the age group chosen was 20 - 21 years. They recorded a mean height of 151.1 cm, and all of them were anaemic. Non-anaemic women volunteers were not available for the study. Adolescent boys in the age range of 17-18 years were selected for the study. The anaemic boys recorded a mean height of 165.6 cm against 166.8 cm recorded by the non-anaemic group.

The mean weight of the anaemic male volunteers was 48.3 kg as against 50.0 kg registered by non-anaemic group. The mean weights of the anaemic female volunteers was 44 kg. The anaemic boys recorded a mean weight of 47 kg, while the non anaemics recorded a mean weight of 47.8 kg.

The mean weight of the men both anaemic and non-anaemic was lower than 55 kg, the weight of an average Indian man. However the mean weight of women was almost near the average weight of an Indian woman who weighs 45 kg. The mean weight of the adolescent boys was lower when compared to the mean weights of an average adolescent boy.

Statistical analysis of the heights and weights revealed that the differences in heights and weights between anaemic and non-anaemic men and anaemic and non-anaemic boys was not statistically significant. This is essential for the study as great differences in height and work output may influence the work output and energy expenditure of the individual. To attribute the differences in energy expenditure to the state of anaemia, their heights and weights need to be statistically insignificant.

Individual data about heights and weights are in the Appendix 5.

c) Mean serum iron levels of the volunteers:

Table IV putsforth the mean serum iron levels of the anaemic and non-anaemic volunteers at the start of the study.

TABLE IV

MEAN SERUM IRON LEVELS OF THE VOLUNTEERS

Groups	Number	Mean Serum iron levels in µg/100 ml	't' value
Men:			
Anaemic	18	54.9	4.366**
Non-anaemic	4	66.0	
Women:			
Anaemic	19	49.3	
Non-anaemic	—	—	
Adolescent boys:			
Anaemic	38	54.3	4.650**
Non-anaemic	16	69.5	

**Significant at 1 per cent level

According to the Institute of Central America and Panama Nutrition Programme (1972) (INCAPNP) Serum iron levels lower than 45 ug/100 ml indicates high risk, 45 - 59 ug/100 ml indicates moderate risk and above 60 ug/100 ml low risk.

The anaemic men in the present study registered a mean serum iron value of 54.9 ug/100 ml against 66 ug/100 ml recorded by the non anaemic group. The serum iron was levels of the anaemic women was 49.3 ug/100 ml. The anaemic adolescent boys registered 54.3 ug/100 ml against 69.5 ug/100 ml registered by the non-anaemic boys.

Comparing these values with INCAPNP values all the anaemic groups the men, women and adolescent boys were at moderate risk.

Statistical analysis between the values registered by the anaemic and non-anaemic men and between the values registered by the anaemic and non-anaemic adolescent boys revealed that there was a significant difference at 1 per cent level, between both the groups. Individual serum iron values are given in the Appendix 6

d) <u>Mean haemoglobin levels of the volunteers:</u>

Table V presents the mean haemoglobin levels of the volunteers at the beginning of the investigation.

TABLE V

MEAN HAEMOGLOBIN LEVELS OF THE VOLUNTEERS

Groups	Number	Mean Haemoglobin levels in g/100 ml	't' value
Men:			
Anaemic	18	9.7	
Non-anaemic	4	13.3	16.867**
Sauberlich (1976)		12.0	
Women:			
Anaemic	19	8.8	
Non-anaemic	--		
Sauberlich (1976)		10.0	
Adolescent boys:			
Anaemic	38	10.0	
Non-anaemic	16	12.9	19.14**
Sauberlich (1976)		12.0	

**Significant at 1 per cent level

All the 18 adult men were anaemic as per the values of Sauberlich (1976) who considers levels below 12 g/100 ml to be anaemic. The mean value registered by the four non-anaemic men were above the 12 g/100 ml confirming that they were non-anaemic. The anaemic boys had registered 10 g/100 ml and non-anaemic boys had registered 12.9 g/100 ml. The anaemic women had registered a mean value of 8.8 g/100 ml which was really a very low value against 10 g/100 ml of Sauberlich (1976) the minimum they are expected to have.

Statistical analysis between the values registered by the anaemic and non-anaemic men and between the values registered by the anaemic and non-anaemic adolescent boys revealed that the values were significant at 1 per cent level. It was important to choose such volunteers with significantly different values so that it would be possible to attribute the differences in the actvities to the differences in the haemoglobin levels.

Individual haemoglobin values are given in the Appendix 7.

2. Pulse Rate and Blood Pressure of the Volunteers:

Table VI highlights the mean pulse rate of the volunteers participating in the study before and after the activity, recorded at the beinning of the study.

TABLE VI

MEAN PULSE RATE OF THE VOLUNTEERS BEFORE AND AFTER THE ACTIVITY

Group	Number	Pulse Rate Before activity	Pulse Rate After activity
<u>Men:</u>			
Anaemic	18	81	115
Non-anaemic	4	77	111
<u>Women:</u>			
Anaemic	19	82	120
Non-anaemic	—	—	—
<u>Adolescent boys:</u>			
Anaemic	38	76	124
Non-anaemic	16	75	121

As is evident from Table VI there was an increase in pulse rate after doing activities like profile milling, match lapping and rough lapping in men; slot milling and lapping in case of women, and making a furrow for sugar cane plantation in the case of adolescent boys. The difference was observed among all volunteers irrespective of whether they were anaemic or non-anaemic. However it was noticed that the rate of increase in the pulse rate was more for the anaemic men and anaemic adolescent boys when compared with their non-anaemic counterparts. This increased pulse rate among anaemic men and adolescent boys may indicate that they had to put in a higher effort to do the same activity, because they were anaemic. Individual pulse rates observed before and after the activity is given in the Appendix 8.

Table VII depicts the mean blood pressure of the volunteers before and after the activity for a specified period of time.

TABLE VII

MEAN BLOOD PRESSURE BEFORE AND AFTER THE ACTIVITY

Groups	Number	Blood pressure	
		Before activity	After activity
Men:			
Anaemic	18	120/81	133/86
Non-anaemic	4	121/79	130/83
Women:			
Anaemic	19	118/79	133/84
Non-anaemic	—	—	—
Adolescent boys:			
Anaemic	38	118/80	134/81
Non-anaemic	16	120/82	129/83

Both the systolic pressure and diastolic pressure appeared to increase on performing the activity irrespective of whether they were anaemic or non-anaemic adults or adolescents.

Individual blood pressure observed before and after the activity are given in the Appendix 9.

3. Energy Expenditure of the Volunteers as Estimated with Kofranyi Michaelis Respirometer:

The energy expended for the different activities by adult men volunteers both anaemic and non-anaemic is shown against their haemoglobin values in Table VIII.

TABLE VIII

ENERGY EXPENDED BY MALE VOLUNTEERS FOR THREE DIFFERENT ACTIVITIES

Activity	Number	Mean haemoglobin level in g/100 ml	Mean energy expenditure in Kcal/mt
Anaemic men:			
Profile milling	6	9.7	4.196
Rough lapping	6	9.6	3.391
Match lapping	6	9.7	3.934
Non-anaemic men:			
Profile milling	-	—	—
Rough lapping	2	13.5	3.028
Match lapping	2	13.2	3.33

Table VIII clearly shows that a mean energy expenditure of 4.196 Kcal/mt was required to undertake profile milling by anaemic men whose mean haemoglobin level was 9.7 g/100 ml. A mean 3.391 Kcal/mt was required to carry out rough lapping by anaemic men whose mean haemoglobin level was 9.6 mg/100 ml. On the other hand only 3.028 Kcal/mt was required by non-anaemic men whose mean haemoglobin lvels was 13.5 g/100 ml. It is evident from this table that men who have a higher haemoglobin level and who are not anaemic expend relatively less energy to perform the same activity when compared to those who are anaemic. This confirms the facts that energy expenditure is reduced with an increase in haemoglobin levels, which might indirectly make it possible for the individual to work for a longer time.

Table IX shows the relationship between energy expended and haemoglobin levels for two activities by adult women volunteers who were anaemic.

TABLE IX

ENERGY EXPENDED BY WOMEN VOLUNTEERS

Activity	Number	Mean haemoglobin level g/100 ml	Mean energy expenditure Kcal/mt
Anaemic women:			
Slot milling	9	8.8	4.140
Lapping	10	8.8	3.604

The mean haemoglobin level of 9 adult women who were doing slot milling and 10 adult women who were doing lapping was 8.8 g/100 ml and the energy expended to carry out these activities were 4.140 Kcal/mt and 3.604 Kcal/mt respectively. Since there were no controls - that is no non-anaemic women doing these activities it was not possible to compare the quantum of energy expended, with haemoglobin levels.

Table X presents the energy expended by adolescent boys for preparing ridges of 1/2 foot height and one foot width of unspecified length in a specified time duration for sugar-cane plantation.

TABLE X

ENERGY EXPENDED BY ADOLESCENT BOYS FOR PREPARING FURROWS

Groups	Number	Mean haemoglobin level g/100 ml	Mean energy expenditure Kcal/mt
Anaemic boys	38	10.0	4.125
Non-anaemic boys	16	12.9	3.801

It is evident from table X that there appears to be an inverse relationship between the mean haemoglobin levels and the energy expended. [illegible]

[illegible]. As the haemoglobin levels increase, there is a decrease in the amount of energy required to carry out a specific activity. In this study the adolescent boys who were anaemic (10 g/100 ml) spent 4.125 Kcal/mt while digging the furrow against the non-anaemic boys (12.9 g/100 ml) who required only 3.801 Kcal/mt for carrying out the same activity. It is possible that those who spend more energy would get exhausted faster than those who spend less energy, in a specified time.

The individual energy expenditure for all the different activities by the different groups of volunteers is given in the Appendix 10.

4. Work Output in Carrying out the Specific Activities:

Table XI brings out the mean work output of the anaemic and non-anaemic adult men and women during a specified time.

TABLE XI

MEAN WORK OUTPUT OF THE VOLUNTEERS

Groups	No	Activity during a eight hour shift	Work output interms of number of pieces	't' value
Men				
Anaemic	6	Profile milling	276	
Anaemic	6	Match lapping	104	1.84
Non-anaemic	2	Match lapping	128	
Anaemic	6	Rough lapping	165	3.047*
Non-anaemic	2	Rough lapping	222	
Women				
Anaemic	9	Slot milling	1100	
Anaemic	10	Lapping	21	

*Significant at 5 per cent level

Table XI reveals that in an eight our shift 276 pieces were turned out inprofile milling by anaemic men. The mean number of pieces turned out in match lapping by anaemic men were 104 against 128 turned out by non-anaemic men. Similarly rough lapping could be done on 165 pieces by anaemic men against 222 pieces by non-anaemic men in the specified time period. These results indicate that non-anaemic men perform better and their work output was higher when compared to the anaemic men. For slot milling 1,100 pieces, and lapping 21 pieces could be completed by anaemic women. No comparisons for this was possible initially as there were no non-anaemic women, performing these activities.

Statistical analysis revealed that the differences in the number of pieces turned out was not significant for match lapping. However the differences for rough lapping was statistically significant at 5 per cent level.

Table XII shows the mean coverage in terms of length by the adolescent boys both anaemics and non-anaemics.

TABLE XII

MEAN LENGTH COVERED BY THE ADOLESCENT BOYS

Groups	Number	Activity for 10 minutes	Work out-put in terms of length covered in feet	't' value
Adolescent Boys:				
Anaemic	38	Preparing furrows	34.8	14.90**
Non-anaemic	16		54.1	

**Significant at 1 per cent level

During a specified period of 10 minutes the anaemic boys prepared furrows of 34.8 feet lenght while for the same time non-anaemic boys could prepared furrows of 54.1 feet length which was about one and half times more length covered than that covered by the anaemic boys. Again here it appears that the work output by non-anaemic boys is considerably higher than that of the anaemic boys, indicating that anaemia affects the work output.

Difference between the length covered by the anaemic and non-anaemic boys was statistically found to be significant at 1 per cent level.

The individual work output by all the different groups of volunteers is given in Appendix 11.

5. <u>Physical Work Capacity with an Electrical Ergometer:</u>

Table XIII depicts the physical work capacity and pulse rate before and after ergometry.

TABLE XIII

PHYSICAL WORK CAPACITY AND PULSE RATE BEFORE AND AFTER ERGOMETRY

Groups	Number	Resistance applied in watts	Time required for exhaustion inseconds	Mean pulse rate	
				before ergometry	After ergometry
Men					
Anaemic	6	275	89	79	149
Non-anaemic	-	—	—	—	—
Women					
Anaemic	9	68.75	68	77	148
Non-anaemic	-	—	—	—	—
Adolescent boys					
Anaemic	38	275	101	78	144
Non-anaemic	16	275	118	76	141

While the resistance applied was 275 watts, the anaemic men got exhausted in an ergometry in89 seconds. The anaemic women got exhausted in 68 seconds with a resistance of 68.75 watts. The anaemic adolescent boys for whom a resistance of 275 watts was applied got exhausted in 101 seconds of recorded by non-anaemic boys.

This again goes to prove that for non-anaemics enduring physical capacity is more than the anaemics.

The pulse rate had increased for all the groups after ergometry, irrespective of whether they were anaemic or non-anaemic.

The individual pulse rate and the time required for exhaustion on an ergometer is given in the Appendix 12.

6. Impact of Iron Supplementation on the Volunteers:

Table XIV putsforth the mean serum iron levels before and after supplementation with iron tables.

TABLE XIV

MEAN SERUM IRON LEVELS BEFORE AND AFTER SUPPLEMENTATION

Groups	Number	Mean Serum Iron µg/100 ml		't' value
		Before supplementation	After supplementation	
Men				
Anaemic	18	54.9	75.6	12.12**
Women				
Anaemic	19	49.3	70.3	13.02**
Adolescent boys				
Anaemic	38	54.3	74.7	9.585**

**Significant at 1 per cent level

Adult anaemic men recorded a mean serum iron value of 54.9 µg/100 ml before supplementation which rose to 75.6 µg/100 ml after supplementation. For adult anaemic women the value increased from 49.3 µg/100 ml to 70.3 µg/100 ml. and for adolescent anaemic boys the value increased from 54.3 µg/100 ml to 74.7 µg/100 ml. Statistical analysis of the data revealed a significance at 1 per cent lvel, between all the groups, before and after supplementation.

This confirms the beneficial effects of iron supplementation for all the groups with respect to their serum iron levels.

The rise in serum iron levels is given in Appendix 13.

Table XV presents the mean haemoglobin levels before and after supplementation with iron tablets.

TABLE XV

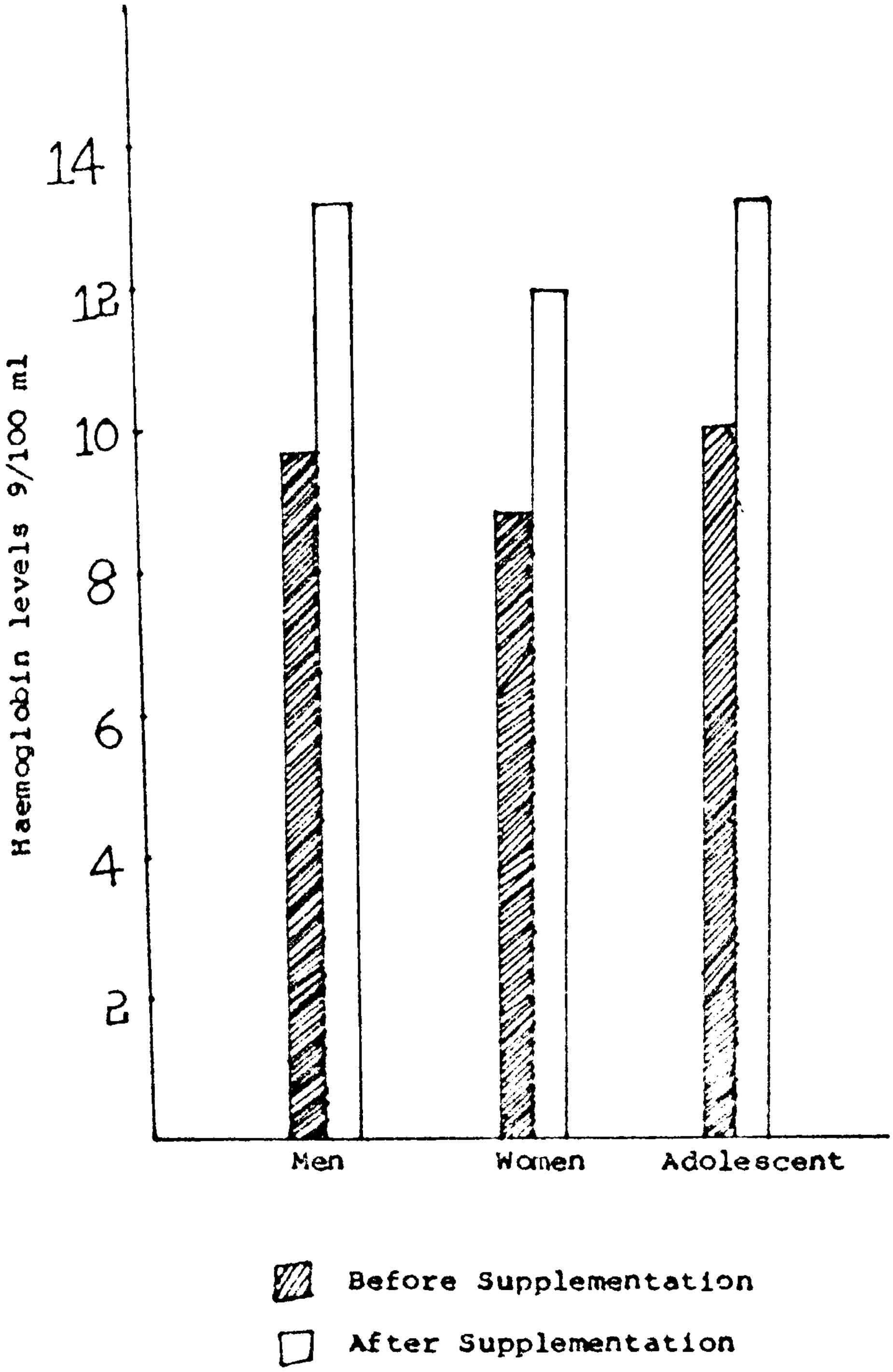
MEAN HAEMOGLOBIN LEVELS BEFORE AND AFTER SUPPLEMENTATION WITH IRON TABLETS

Groups	Number	Mean Haemoglobin level in g/100 ml		't' value
		Before supplementation	After supplementation	
<u>Men</u>				
Anaemic	18	9.7	13.2	11.6**
Sauberlich (1976)		12.0		
<u>Women</u>				
Anaemic	10	8.8	11.9	20.31**
Sauberlich (1976)		10.0		
<u>Adolescent boys</u>				
Anaemic	38	10.0	13.4	7.79**
Sauberlich (1976)		12.0		

**Significant at one per cent level

As is evident in table XV the mean haemoglobin levels had increased for anaemic men from 9.7 g/100 ml to 13.2 g/100 ml for anaemic women from 8.8 g/100 ml to 11.9 g/100 ml and for anaemic adolescents boys from 10 g/100 ml to 13.4 g/100 ml. Statistical analysis revealed that the increase was statistically significant at 1 per cent level for all the groups. This brings out the beneficial effects of

Figure B HAEMOGLOBIN VALUES BEFORE AND AFTER IRON SUPPLEMENTATION



supplementation of iron to the anaemic men, women and adolescent boys with their haemoglobin levels. The same is seen evidently in figure 8.

Similar increases in haemoglobin after supplementation with iron has been reported by Basta *et al* (1979) who found that after 60 days of supplementation the haemoglobin values increased significantly.

The rise in haemoglobin levels in the anaemics is given in the Appendix 14.

Table XVI brings forth the mean differences in the pulse rate before and after activity; before and after supplementation.

TABLE XVI

MEAN PULSE RATE OF VOLUNTEERS

Groups	Number	Pulse Rate: Before supplementation — Before activity	Pulse Rate: Before supplementation — After activity	Pulse Rate: After supplementation — Before activity	Pulse Rate: After supplementation — After activity
<u>Men</u>					
Anaemic	18	81	115	78	111
<u>Women</u>					
Anaemic	19	82	120	80	116
<u>Adolescent Boys</u>					
Anaemic	38	76	124	73	122

It is natural that the pulse rate increases after any physical work. It was interesting to note in the present study that in all the groups studied, the rate of increase in puse rate after supplementation was lower after performing the same activity as compared to the rate of increase in the pulse rate before supplementation. This probably indicates that the body exerts less when normal haemoglobin and serum iron levels are achieved, for performing an actvity and has to exert more to perform the same activity if anaemic.

Iron supplementation may be benefical in maintaining the pulse rate normal.

The individual pulse rate after iron supplementation is given in the Appendix 15.

Table XVII highlights the blood pressure levels before and after activity, before and after supplementation.

TABLE XVII

MEAN BLOOD PRESSURE BEFORE AND AFTER SUPPLEMENTATION

Groups	Number	Blood Pressure			
		Before supplementaton		After supplementation	
		Before activity	After activity	Before activity	After activity
Men					
Anaemic	18	120/81	133/85	120/82	130/85
Women					
Anaemic	19	118/79	133/84	119/77	127/84
Adolescent Boys					
Anaemic	38	118/80	134/81	121/81	131/81

There may be a mild change in blood pressure after activity. In the present study the change in blood pressure was comparatively less after supplementation than before supplementation for all groups studied.

The individual blood pressure after supplementation is given in the Appendix 16.

Table XVIII brings out the impact of supplementation on the energy expenditure of the volunteers.

TABLE XVIII

IMPACT OF SUPPLEMENTATION OF THE ENERGY EXPENDITURE

Activity	Number	Mean energy expenditure Kcal/mt. Before supplementation	After supplementation	't' value
Anaemic men				
Profile milling	6	4.196	3.526	4.35**
Rough shapping	6	3.391	3.064	3.08*
Match lapping	6	3.934	3.289	3.76**
Anaemic women				
Slot milling	9	4.140	3.524	5.133**
Lapping	10	3.604	3.200	6.92**
Anaemic adolescent boys	38	4.125	3.701	6.704**

** Significant at 1 per cent level
* Significant at 5 per cent level

The mean energy expenditure in K.Cal/minute was less for all the groups studied for the various activities when compared with the before supplementation values. And the differences between the before supplementation values and after supplementation values were significant at 1 per cent level for all the groups and for all activities with the exception of rough lapping where the significance was at 5 per cent. These results indicate that the iron supplementation may be helpful in conserving energy and post-poning exhaustion.

Individual energy expenditure after supplementation is given in the Appendix 17.

Table XIX tabulates the impact of supplementation on the physical work capacity and energy expenditure on an ergometer.

TABLE XIX

IMPACT OF SUPPLEMENTATION ON PHYSICAL WORK CAPACITY AND ENERGY EXPENDITURE ON AN ERGOMETER

Groups	Number	Resistance in watts	Time required for exhaustion in seconds		Energy expended on ergometer in Kcal/mt		't' value for energy expended
			Before supplementation	After supplementation	Before supplementation	After supplementation	
Men							
Anaemic	6	275	89	122	5.188	4.736	2.306*
Women							
Anaemic	9	68.75	68	82	5.154	4.731	3.02**
Adolescent boys							
Anaemic	38	275	101	140	5.057	4.553	6.00**

* Significant at 5 per cent level
** Significant at 1 per cent level

The anaemic adult men and adolescent boys got exhausted in an ergometer in 89 and 101 seconds respectively before iron supplementation and the same men and boys after iron supplementation and improved haemoglobin levels got exhausted in the same ergometer applying the same resistance of 275 watts only after 122 and 140 seconds respectifely.

The anaemic adult women got exhausted in an ergometer in 68 seconds before iron supplementation and the same women after iron supplementation and improved haemoglobin levels got exhausted in the same ergometer, applying the same resistance of 68.75 watts only after 82 seconds.

This ability to perform an actvity under resistance for an increased amount of time in all the groups may be attributed to iron supplementation. Gopalan (1975) endorses this view by reporting that work output depends on physical efficiency and anaemia profoundly affects the work performance.

The energy expenditure while working on the ergometer was also recorded and the results revealed that in all the groups studied the energy expended was more before iron supplementation and the same reduced after supplementation. For adult men it was reduced from 5.188 Kcal/mt to 4.736, for adult women from5.154 to 4.731 Kcal/mt and for adolescent boys from 5.057 to 4.553 Kcal/mt respectively.

Statistical analysis revealed that the energy expended before and after supplementation in adolescent boys and in women was significant at 1 per cent level while in the men it was significant at 5 per cent level.

It is evident from the foregoing analysis that to perform the same activity for the same amount of time the energy value can be reduced if the haemoglobin levels could be improved.

The energy expended and the time required for exhaustion on an ergometer is given in the Appendix 18.

Table XX brings forth the impact of iron supplementation on the work output by the different groups of volunteers studied.

TABLE XX

IMPACT OF IRON SUPPLEMENTATION ON WORK OUTPUT

Activity	Number	Mean work output in terms of pieces: Before supplementation	After supplementation	't' value
Anaemic men				
Profile milling	6	276	350	4.40**
Rough lapping	6	165	237	4.75**
Match lapping	6	104	141	4.66**
Anaemic women				
Slot milling	9	1100	1208	2.699*
Lapping	10	21	31	4.52**
Anaemic boy				
Preparing a furrow	38	34	60	16.18**

*Significant at 5 per cent level
**Significant at 1 per cent level

Men who were anaemic at the start of the study and subsequently became non-anaemic because of iron supplementation, turned out 350 pieces in profile milling in an eight hour shift against only 276 pieces turned out before supplementation. For rough lapping it was 237 pieces after supplementation against 165 pieces before supplementation, and for match

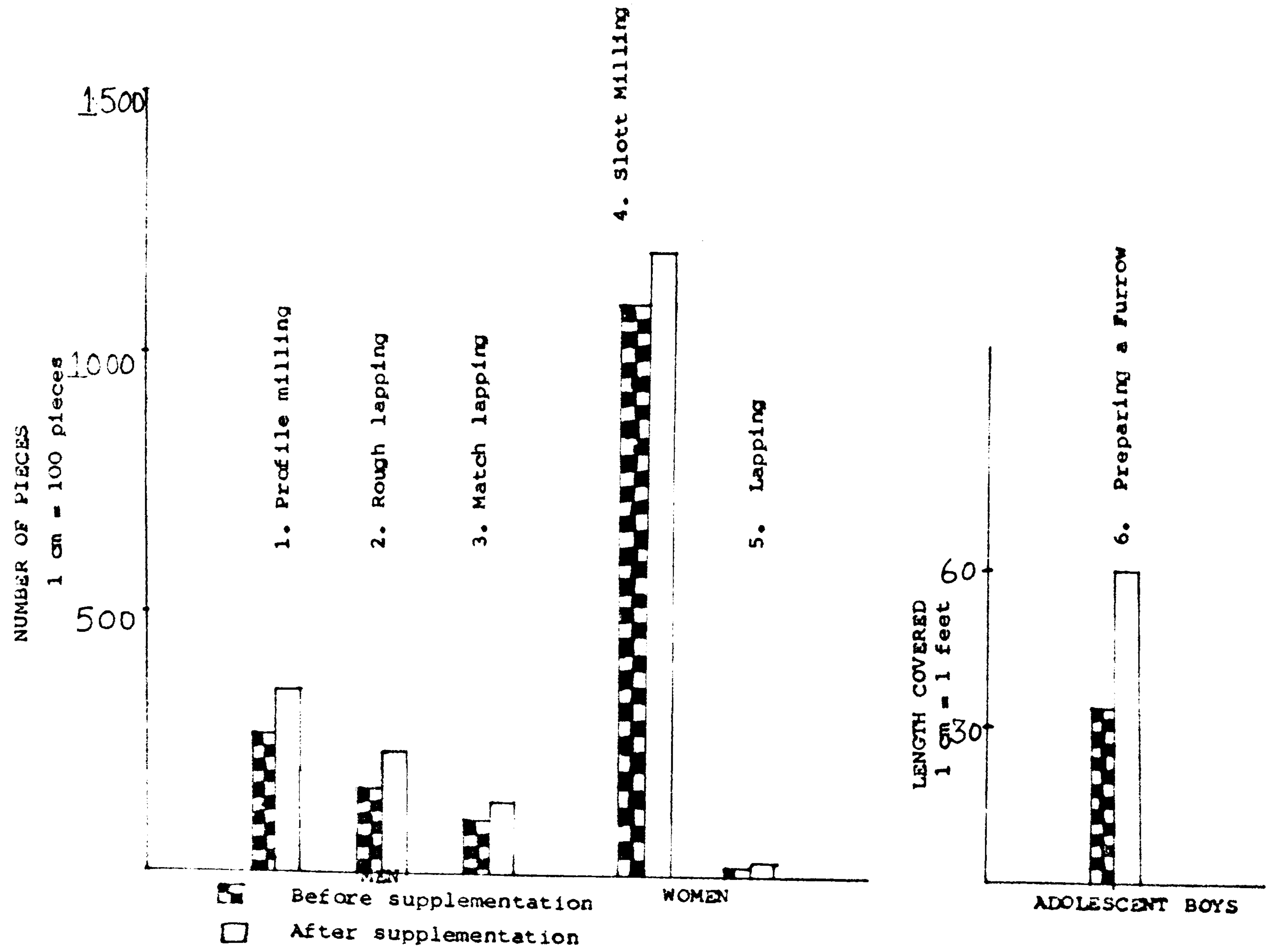


Figure C INCREASE IN WORK OUTPUT ON IRON SUPPLEMENTATION lapping it was 141 pieces after supplementation against 104 pieces before supplementation.

Women who were anaemic at the start of the study and subsequently became non-anaemic because of iron supplementation turned out 1,208 pieces against 1,100 in slot milling and 31 pieces against 21 pieces in lapping after supplementation.

Adolescent boys were anaemic at the start of the study but subsequently became non-anaemic because of the iron supplementation prepared a ridge of 60 feet against 34 feet before supplementation. Statistical analysis depicts a 1 per cent significance between before and after supplementation, among the different groups except for slot milling where it was significant at 5 per cent lvel. Figure C shows the increase in work output diagramatically.

This view that iron supplementation increases the work output is endorsed by Edgerton et al. (1979).

These results bring home the fact that iron supplementation is definitely beneficial in improving the work output of adultmen, women as well as adolescent boys.

The individual increase in work output on iron supplementation is given in theAppendix.19

V. SUMMARY AND CONCLUSION

V. SUMMARY AND CONCLUSION

The study on "Anaemia and work output " was carried out with the objective of finding the relationship between anaemia and work output and the impact of iron supplementation on selected anaemic men, women and adolescent volunteers. Non-anaemic volunteers were available and studied for men and adolescent boys.

The anaemic volunteers were studied with reference to their dietary intake, haemoglobin and serum iron levels, work output in terms of number of pieces turned out, pulse and blood pressure rates, energy expenditure and physical work capacity on an ergometer. The values achieved by the anaemics were compared with the non-anaemics.

Each of the anaemic volunteers were fed 60 mg of elemental iron every day for 120 days. After this period of supplementation the volunteers were studied again for the various factors mentioned above, and compared with before supplementation values. The results of the study indicated the following facts.

1. The mean food intake of the non-anaemics was better than the anaemic volunteers, specialy with reference to iron rich foods. However in general the intake of all the foods and nutrients were below recommended allowances for both the groups.

2. The mean serum iron and haemoglobin levels increased after supplementation for all the anaemic groups and had recorded normal values.

3. The extent of increase in pulse rate and blood pressure were relatively less after supplementation while performing the same kind of activities, indicating probably a better cardiac and pulmonary efficiency.

4. Iron supplementation conserves energy and haemoglobin levels seem to have an inverse relationship with the energy expended.

5. The work output was increased after supplementation suggesting that iron deficiency anaemia decreases the productivity and supplementation with iron improves work output. This was clearly seen in regard to their different activities.

6. The physical work capacity on an ergometer improved significantly after supplementation.

These results lead us to the conclusion that iron supplementation is definitely beneficial to working population groups and their work output can be remarkably increased by suitable supplementation.

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APPENDICES

APPENDEX - 1

ESTIMATION OF SERUM IRON - DIPYRIDYL METHOD

PRINCIPLE:

Ferrous iron gives a pink color with 2,2 dipyridyl. A solution of dipyridyl in acetic acid is added to serum followed by a reducing agent. Protein are removed by heating in boiling water and then centrifuging.

REAGENTS

1. 2,2 dipyridyl - 0.1 percent acetic acid 3 percent V/V
2. Sodium sulphate 0.1 m
3. Chloroform
4. Standard solution containing 200 micrograms of iron/ml
5. Working standard - dilute 3 ml of the stock solution to 100 ml with water to obtain a solution containing 3 mg/ml.

PROCEDURE

Mix equal volumes of serum, 0.1 m sodium sulphate, and dipyridyl reagent in a glass stippered tube which can be centrifuged. Heat in boiling water for five minutes. Cool and add 0.1 ml of chloroform, stopper and shake vigourely for five minutes at 300 r.p.m. If the supernatent is not completely clear, repeat the shaking and centrifuging. Read at 520 mℓ standard in the same way.

Calculation

Micrograms iron per 100ml of the serum

$$= \frac{\text{Readings of unknown}}{\text{Readings of standard}} \times 300$$

The readings are linear with concentration to at least 500 per 100ml. To obtain acalibration curve, dilute 5 ml of the stock standard to 100 ml with water and set up tubes containing 0.4, 0.8, 1.2, 1.6 and 2.0 ml of this, make each to 2 ml with water and develop the color as described above and read against the blank. These correspond to 100, 200, 300, 400 and 500 ug per 100ml.

APPENDIX - 2

ESTIMATION OF HAEMOGLOBIN BY CYANMETHAEMOGLOBIN METHOD

The haemoglobin is treated with a reagent containing potassium ferricyanide, potassium dihydrogen phosphate. The ferricyanide forms methaemoglobin which is converted to cyanmethaemoglobin by the cyanide.

REAGENTS

1. Drapkin's diluent solution

sodium bicarbonate	1 g
Potassium cyanide	0.05 g
Potassium ferricyanide	0.2 g
Distilled water	1 litre

This solution is preserved in a dark bottle and preferably under cold storage. Its preparation and handling should be done with great care. This solution should not be used after it forms a precipitate at the bottom of the storage bottle.

PROCEDURE

1. Exactly 5 ml of the drabkin's diluent solution is measured in to a dry testtube from a burette (or) a pipette with suction bulb.
2. Exactly 0.02 ml of blood is transferred from a standard haemoglobin pipette into a diluent solution.

Usual care in filling and cleaning of loaded haemoglobin pipette must be observed.

3. The pipette is rinsed three times with the diluent solution without allowing the formation of air bubbles in the solution.

4. The blood and the diluent are thoroughly mixed by rotating the tube.

5. Ten minutes time is allowed for the formation of cyanmethaemoglobin.

6. 5 ml of diluent solution is used as blank.

7. The readings are taken in photoelectric colorimeter at 540 $m\mu$.

<u>Caliberation Procedure:</u>

1. Total blood iron is determined by Wong's method which would give absolute amount of haemoglobin.

2. Exactly 0.02 ml of this known blood sample is measured into 5.0, 7.5, 10.0, 12.5 and 15.0 ml of diluent solution. These are now equivalent to blood samples containing respectively 100, 67, 50, 40 and 30 percent of the original haemoglobin concentration.

3. The intensity of the color is read using a green fitter at 540 $m\mu$ against a blank set at zero optical density.

Determination of Iron and Haemoglobin – Wong's Method.

Principle:

The iron is detached from the haemoglobin molecubes by treatment with concentrated sulphuric acid in the presence of potassium per-sulfate without heating. After removal of the proteins by tungstic acid, the iron in the filtmate is determined colorimetrically. From the total iron content, the haemoglobin content is readilly obtained, since the haemoglobin content is 0.34 percent of iron and only 1 to 2 percent or less of the total blood iron is nonhaemoglobin iron.

Reagents:

1. 10% Sodium tungstate
2. Saturated potassium persulphate solution
3. Potassium cyanide
4. Standard iron solution
5. Working standard.

Procedure:

With an ostwald (or) micropipette, accurately transfer 0.[illegible]ml of well mixed oxalate whole blood into a 50 ml volumetric flask. Add 2 ml of saturated potassium persulphate solution. Mix and dilute to about 25 ml with water. Add 2 ml of 10 percent sodium tungstate solution.

Mix and cool to room temperature under the tap, and dilute to volume with water. Stopper and mix by inversion, filter through a dry, paper, collecting the filtrate in a dry flask. Prepare a standard in a second 50 ml volumetric flask by addition of 2 ml of concentrated sulphuric acid, 2 ml of saturated potassium per sulphate and 2.5 ml of standard iron solution containing 0.1 mg of ferric iron per ml. Cool to room temperature, dilute with water to the mark and mix. Prepare a blank similar to the standard but omitting the standard iron solution.

Measure 20 ml of unknown filterate, standard and blank if, necessary into seperate test-tubes. To each add 0.5 ml of saturated persulphate solution followed by 2 ml of 3 N potassium thiocyanide solution. Mix by inversion and read within the next thirty minutes, setting the colorimeter to zero density with the blank at 480 mµ.

<u>Calculation:</u>

$$\frac{\text{Density of unknown}}{\text{Density of Standard}} \times 0.25 \times \frac{100}{0.5} \times \frac{1}{3.4}$$

= Grams of haemoglobin per 100 ml of blood

APPENDIX - 3

FORMULA FOR CONVERSION OF RESPIROMETER DATA TO OXYGEN UNITS.

The data are to be converted to the amounts of oxygen consumed in terms of cubic centimeter minute using the following formula.

1. Corrected volume of air = Gas meter reading X Correction factor (in lit)
2. Corrected volume of air at normal temperature and pressure of air

$$= \text{Corrected volume of air} \times \frac{273}{760} \times \frac{\text{Atmospheric pressure in mm Hg}}{273 + \text{observed temperature.}}$$

3. Correction for oxygen consumption (K)

$$= \frac{\text{Number of minutes the expired air was kept in the rubber bladder} \times 0.04}{\text{Corrected volume of air at normal temperature and pressure} \times \text{rate at which the expired air was collected.}}$$

4. Corrected volume of oxygen

= percentage of oxygen in the expired air - K

5. Volume of oxygen consumed

= percentage of oxygeb in the atmosphere air – corrected volume of oxygen

6. Total oxygen consumed per minute

$$= \frac{\text{Corrected volume of air at NTP X Volume of oxygen consumed}}{\text{Number of minutes the expired air was kept in the rubber bladder X 100}}$$

7. Cubic centimeter of oxygen = Total oxygen consumed / minute X 1000

Conversion to Calories = $\frac{\text{Cubic centimeter of oxygen / minute X 4.86}}{1000}$

= Calorie/minute

<u>Note :</u> 1. Correction factor for the reading of the respirometer = 1.024

2. Rate at which the expired air was collected = 0.6 percent or 0.3 percent of the total air.

3. Percentage of oxygen in the atmosphere air = 20.97 percent.

APPENDIX 4

FOOD INTAKE IN MALES.

Foodstuffs(g)	Anaemics								Non Anaemics	
	1	2	3	4	5	6	7	8	9	10
Cereal	300	200	400	520	300	400	900	300	400	350
Pulses	35	20	50	35	35	45	90	40	45	25
Green leafy vegetables	0	0	50	0	0	0	50	0	0	50
Other vegetables	45	135	45	70	35	50	55	35	60	0
Roots + Tubers	40	80	10	20	15	50	55	60	25	0
Fruits	25	25	0	75	0	50	0	25	50	0
Milk	200	175	200	275	250	300	150	250	250	150
Fats and oils	25	20	20	15	20	20	35	20	20	20
Sugar	25	15	15	15	30	25	30	25	25	30
Nut	10	25	20	25	25	20	20	25	10	25

FOOD INTAKE IN WOMEN

Foodstuffs (g)	VOLUNTEERS									
	1	2	3	4	5	6	7	8	9	10
Cereals	290	260	225	250	330	350	280	260	275	220
Pulses	55	50	30	35	35	35	40	40	40	35
Green Leafy Vegetables	0	0	0	0	40	0	0	0	0	20
Other Vegetables	70	45	35	35	35	45	35	75	30	75
Roots and Tubers	10	55	70	25	55	75	95	35	40	60
Fruits	30	0	50	0	0	0	75	75	25	100
Milk	340	300	250	250	200	300	250	300	350	300
Fats & Oils	20	35	20	35	20	25	20	0	25	15
Meat and Fish	30	0	0	0	0	0	0	0	0	0
Sugar & Jaggery	15	30	30	25	25	25	25	30	25	25
Egg	30	0	0	0	0	0	50	0	0	0
Nuts	10	20	25	0	25	25	50	25	20	10

FOOD INTAKE IN ADOLESCENT BOYS

	Anaemics							Non Anaemics		
Foodstuffs (g)	1	2	3	4	5	6	7	8	9	10
Cereals	300	600	500	500	400	350	400	600	620	500
Pulses	30	45	50	40	40	35	30	35	50	20
Green Leafy Vegetables	0	0	0	0	0	0	0	15	25	0
Other Vegetables	40	25	75	90	35	25	20	70	75	20
Roots & Tubers	0	80	45	85	55	40	30	45	45	45
Fruits	50	50	25	0	0	0	0	75	60	50
Milk	150	150	350	275	100	235	150	275	250	200
Fats & Oils	20	20	15	20	15	15	20	20	20	20
Sugar & Jaggery	15	15	30	30	30	30	20	15	15	15
Nuts	20	25	20	10	10	25	20	85	25	0

NUTRIENT INTAKE IN MALES

Nutrients	Anaemics							Non-Anaemics		
	1	2	3	4	5	6	7	8	9	10
Protein (g)	37	30	49	53	65	54	49	54	56	53
Energy (K cal)	1730	2178	2135	1914	1599	2002	2581	2905	3145	1918
Calcium (mg)	475	214	502	178	179	617	535	114	612	508
Iron (mg)	15	12	23	21	13	28	26	29	31	25
Retenol (µg)	2132	1244	94	556	101	129	72	777	992	64
Thiamine (mg)	1.01	0.54	1.47	0.6	0.92	1.57	0.65	0.64	2.53	1.51
Riboflavin (mg)	0. 88	0.76	0.35	0.58	0.49	1.07	0.95	0.58	0.98	0.55
VitaminC (mg)	42.6	91.7	63.6	16.9	15.4	14.8	21.07	46.05	35.2	62.2

NUTRIENT INTAKE IN WOMEN

Nutrients	Volunteers									
	1	2	3	4	5	6	7	8	9	10
Protein (g)	56	43	38	40	36	45	49	54	42	36
Energy (K cal)	2108	1815	1699	2080	1751	2090	1900	2009	1730	2000
Calcium (mg)	619	523	596	541	381	596	465	572	835	582
Iron (mg)	20	15	17	11	14	18	16	14	14	26
Retinol (μg)	682	74	166	37	999	57	192	103	1014	656
Thiamine (mg	1.3	1.2	3.0	0.6	0.9	1.5	1.6	1.6	0.5	0.7
Riboflavin (mg)	2.4	1.2	0.8	0.7	0.8	1.3	0.7	1.1	1.1	0.9
Vitamin C (mg)	44	42	29	21	22	40	53	38	100	62

NUTRIENT INTAKE IN ADOLESCENT BOYS

Nutrients	Anaemics						Non Anaemics			
	1	2	3	4	5	6	7	8	9	10
Protein (g)	32	62	58	25	48	88	42	65	59	52
Energy (K cal)	1848	2771	2575	2484	2791	1866	2738	2740	2909	2404
Calcium (mg)	239	300	204	599	320	304	387	500	497	261
Iron (mg)	17	29	20	24	16	19	16	25	27	23
Retenol (µg)	172	133	987	40	58	82	33	405	586	118
Thiamine (mg)	0.99	1.4	0.64	0.8	1.7	1.4	0.51	0.78	1.07	1.40
Riboflovin (mg)	0.514	0.94	0.75	0.65	0.49	0.59	0.53	0.53	0.70	0.98
Vitamin C (mg)	36.85	26.95	24.05	20.25	28.15	12.35	20.32	62	75	20

APPENDIX – 5

INDIVIDUAL HEIGHTS AND WEIGHTS OF MALES

Anaemic group				Non Anaemic group			
Number	Age in years	Height in cm	Weight in kg	Number	Age in years	Height in cm	Weight in kg
1	24	169	45	1	25	165	50
2	25	170	45	2	24	161	49
3	24	162	46	3	25	165	45
4	25	163	52	4	24	165	46
5	25	165	50				
6	24	168	44				
7	24	164	50				
8	25	167	46				
9	25	165	49				
10	25	166	51				
11	25	168	50				
12	24	166	48				
13	25	166	49				
14	24	156	47				
15	25	165	50				
16	25	160	47				
17	25	169	48				
18	24	172	53				

INDIVIDUAL HEIGHTS AND WEIGHTS OF FEMALES

Anaemic group

Number	Age in years	Height in cm	Weight in kg
1	21	150	40
2	21	163	43
3	21	155	41
4	22	152	42
5	20	155	44
6	21	163	46
7	21	158	40
8	21	157	45
9	21	156	47
10	21	153	47
11	20	156	48
12	22	155	45
13	22	154	46
14	22	157	41
15	21	160	43
16	20	159	43
17	21	158	46
18	20	162	45
19	21	163	44

Individual Height and Weights of the Adolescent Boys

Anaemic group				Non-Anaemic group			
Number	Age in years	Height in cm	Weight in kg	Number	Age in years	Height in cm	Weight in kg
1	17	164	43	1	17	164	49
2	17	163	45	2	17	165	50
3	17	160	47	3	17	167	46
4	17	163	42	4	18	169	48
5	17	161	44	5	18	167	46
6	17	164	45	6	18	165	49
7	17	167	49	7	17	165	49
8	18	166	50	8	17	168	52
9	18	171	53	9	17	164	46
10	18	164	51	10	17	165	45
11	18	166	46	11	18	166	46
12	18	161	47	12	18	166	48
13	18	165	49	13	18	167	49
14	18	169	43	14	18	165	48
15	18	162	42	15	18	165	46
16	18	165	43	16	18	165	48
17	18	166	48				
18	17	169	52				
19	17	163	46				

Anaemic group				Non-anaemic group
Number	Age in years	Height in cm	Weight in kg	
20	17	170	43	
21	17	165	47	
22	17	164	48	
23	17	170	55	
24	17	164	47	
25	17	168	52	
26	18	167	43	
27	18	164	44	
28	18	169	49	
29	18	165	50	
30	18	168	46	
31	18	165	45	
32	18	162	44	
33	18	167	45	
34	18	171	53	
35	18	169	52	
36	18	165	45	
37	18	168	51	
38	18	164	45	

APPENDIX - 6

INDIVIDUAL SERUM IRON VALUES OF THE MALES AT THE START OF THE STUDY.

Anaemic group		Non-Anaemic group	
Number	Serum iron µg/100ml	Number	Serum iron µg/100ml
1	50	1	62
2	54	2	65
3	58	3	70
4	58	4	72
5	50		
6	45		
7	54		
8	54		
9	51		
10	60		
11	62		
12	49		
13	56		
14	59		
15	57		
16	59		
17	54		
18	59		

INDIVIDUAL SERUM IRON VALUES OF THE FEMALES AT THE START OF THE STUDY

	Anaemic group
Number	Serum iron µg/100 ml
1	49
2	44
3	43
4	50
5	54
6	52
7	45
8	49
9	44
10	54
11	45
12	49
13	50
14	46
15	54
16	51
17	60
18	52
19	49

INDIVIDUAL SERUM IRON VALUES OF THE ADOLESCENT BOYS AT THE START OF THE STUDY

Anaemic group		Non Anaemic group	
Number	Serum iron µg/100ml	Number	Serum iron µg/100ml
1	55	1	65
2	50	2	61
3	53	3	62
4	52	4	70
5	59	5	75
6	49	6	64
7	49	7	62
8	50	8	65
9	53	9	70
10	57	10	88
11	53	11	70
12	54	12	63
13	55	13	70
14	51	14	71
15	56	15	75
16	52	16	82
17	58		
18	51		
19	54		
20	51		

Anaemic group	
Number	Serum iron µg/100 ml
21	49
22	53
23	53
24	58
25	57
26	50
27	57
28	52
29	53
30	60
31	61
32	63
33	60
34	52
35	57
36	56
37	62
38	50

APPENDIX 7

INDIVIDUAL HAEMOGLOBIN VALUES OF THE MALES AT THE START OF THE STUDY

Anaemic group		Non Anaemic group	
Number	Haemoglobin g/100ml	Number	Haemoglobin g/100 ml
1	9.2	1	13.0
2	9.6	2	13.5
3	10.9	3	13.1
4	10.1	4	13.9
5	9.0		
6	9.5		
7	9.8		
8	9.4		
9	10.1		
10	9.5		
11	9.8		
12	10.0		
13	9.4		
14	9.6		
15	9.8		
16	10.4		
17	9.1		
18	9.3		

INDIVIDUAL HAEMOGLOBIN VALUES OF THE FEMALES AT THE START OF THE STUDY

Anaemic group

Number	Haemoglobin g/100 ml
1	8.9
2	8.9
3	8.7
4	8.9
5	9.3
6	9.1
7	8.7
8	9.2
9	8.1
10	9.0
11	8.2
12	8.9
13	9.0
14	9.2
15	9.1
16	8.9
17	9.0
18	9.1
19	8.4

INDIVIDUAL HAEMOGLOBIN VALUES OF THE ADOLESCENT BOYS AT THE START OF THE STUDY

Anaemic group		Non Anaemic group	
Number	Haemoglobin g/100ml	Number	Haemoglobin g/100 ml
1	10.5	1	12.9
2	9.4	2	12.8
3	10.3	3	12.5
4	9.1	4	13.0
5	10.4	5	13.5
6	9.3	6	12.7
7	9.7	7	12.1
8	9.9	8	12.6
9	10.1	9	13.1
10	11.0	10	13.9
11	10.5	11	12.8
12	9.8	12	12.7
13	10.9	13	13.0
14	9.6	14	12.6
15	10.8	15	12.5
16	9.9	16	13.9
17	10.7		
18	9.6		
19	10.5		
20	10.1		

Anaemic group	
Number	Haemoglobin g/100ml
21	9.6
22	9.7
23	9.1
24	9.8
25	9.2
26	9.7
27	10.5
28	10.0
29	9.9
30	11.6
31	10.5
32	11.0
33	10.4
34	9.9
35	9.6
36	9.4
37	10.5
38	9.1

APPENDIX 8

INDIVIDUAL PULSE RATE IN MALES AT THE START OF THE STUDY

Number	Profile milling	
	Before activity	After activity
1	84	119
2	82	117
3	76	112
4	79	115
5	84	120
6	82	118

INDIVIDUAL PULSE RATE IN MALES PERFORMING MATCH LAPPING AT THE START OF THE STUDY

Anaemic			Non Anaemic		
Number	Before activity	After activity	Number	Before activity	After activity
1	81	115	1	78	112
2	83	115	2	76	110
3	79	113			
4	82	116			
5	80	114			
6	79	113			

INDIVIDUAL PULSE RATE IN MALES PERFORMING ROUGH LAPPING AT THE START OF THE STUDY

Anaemic			Non Anaemic		
Number	Before activity	After activity	Number	Before activity	After activity
1	83	115	1	76	109
2	81	113	2	74	110
3	81	113			
4	79	111			
5	83	115			
6	83	115			

INDIVIDUAL PULSE RATE IN FEMALES AT THE START OF THE STUDY

Number	Slot milling		Number	Lapping	
	Before activity	After activity		Before activity	After activity
1	85	127	1	80	113
2	82	127	2	83	112
3	83	128	3	81	112
4	82	126	4	80	112
5	81	125	5	81	109
6	83	125	6	80	112
7	83	127	7	80	112
8	81	125	8	80	113
9	85	130	9	79	109
			10	83	115

INDIVIDUAL PULSE RATE IN ADOLESCENT BOYS AT THE START OF THE STUDY

Anaemic			Non Anaemic		
Number	Before activity	After activity	Number	Before activity	After activity
1	74	122	1	75	122
2	80	126	2	72	123
3	76	123	3	76	122
4	80	126	4	76	123
5	74	124	5	73	119
6	79	125	6	74	122
7	75	124	7	79	126
8	76	127	8	76	122
9	76	125	9	75	118
10	74	122	10	70	119
11	74	123	11	76	122
12	77	127	12	76	122
13	72	123	13	75	121
14	77	128	14	77	119
15	73	123	15	77	123
16	76	127	16	77	119
17	73	124			

	Anaemic	
Number	Before activity	After activity
18	73	122
19	74	123
20	76	125
21	77	127
22	77	124
23	80	126
24	77	122
25	79	125
26	77	133
27	74	123
28	76	124
29	76	123
30	70	121
31	72	123
32	74	122
33	74	122
34	76	123
35	78	122
36	79	125
37	74	123
38	80	126

APPENDIX 9

INDIVIDUAL BLOOD PRESSURE IN MALES PERFORMING PROFILE MILLING AT THE START OF THE STUDY

Number	Before activity	After activity
1	110/80	130/84
2	120/82	132/80
3	120/92	140/90
4	120/80	130/84
5	115/75	130/85
6	120/90	134/92

INDIVIDUAL BLOOD PRESSURE IN MALES PERFORMING MATCH LAPPING AT THE START OF THE STUDY

Anaemic			Non Anaemics		
Number	Before activity	After activity	Number	Before activity	After activity
1	120/85	132/80	1	115/75	130/80
2	122/76	134/82	2	120/80	128/90
3	120/80	136/90			
4	124/84	134/82			
5	122/78	135/82			
6	120/90	138/80			

INDIVIDUAL BLOOD PRESSURE IN MALES PERFORMING ROUGH LAPPING AT THE START OF THE STUDY

Anaemic			Non Anaemic		
Number	Before activity	After activity	Number	Before activity	After activity
1	115/75	132/84	1	120/80	132/82
2	126/80	135/92	2	125/78	130/80
3	124/80	135/85			
4	120/90	135/82			
5	115/75	130/84			
6	118/80	130/82			

INDIVIDUAL BLOOD PRESSURE IN FEMALES AT THE START OF THE STUDY

Number	Slot milling Before activity	Slot milling After activity	Number	Lapping Before activity	Lapping After activity
1	120/80	128/82	1	115/75	134/82
2	110/70	126/80	2	114/82	138/86
3	115/75	120/84	3	122/80	134/82
4	120/70	138/90	4	120/80	138/82
5	112/88	134/85	5	120/78	138/90
6	120/80	128/82	6	115/75	136/85
7	108/75	128/84	7	120/80	138/86
8	120/80	128/82	8	128/84	134/82
9	115/75	128/86	9	126/82	132/82
			10	120/80	125/85

INDIVIDUAL BLOOD PRESSURE OF THE ADOLESCENT BOYS AT THE START OF THE STUDY

Anaemic group			Non Anaemic group		
Number	Before activity	After activity	Number	Before activity	After activity
1	110/80	130/86	1	115/75	128/80
2	115/80	136/80	2	120/80	130/80
3	110/75	132/80	3	115/90	128/90
4	120/80	130/80	4	125/95	130/80
5	120/70	130/86	5	120/80	128/85
6	120/90	138/80	6	122/82	130/80
7	110/70	130/80	7	124/84	128/80
8	110/75	132/82	8	120/92	128/84
9	115/75	135/82	9	115/70	130/80
10	120/85	140/80	10	128/70	132/82
11	125/95	136/82	11	122/75	130/80
12	120/80	135/86	12	115/70	130/82
13	115/75	140/82	13	115/78	130/84
14	115/70	132/82	14	120/90	128/86
15	110/82	130/82	15	120/80	128/86
16	120/80	135/86	16	120/75	132/82
17	110/80	138/82			
18	120/80	132/82			
19	115/75	136/80			
20	122/80	135/86			

Anaemic group

Number	Before activity	After activity
21	120/80	132/80
22	128/84	132/86
23	124/78	132/86
24	120/90	135/86
25	115/75	134/80
26	110/80	134/80
27	125/75	138/86
28	115/80	135/86
29	120/90	135/86
30	128/80	146/80
31	120/80	136/80
32	120/80	140/80
33	126/80	138/86
34	126/82	135/86
35	125/75	130/84
36	115/75	132/86
37	120/90	132/80
38	115/75	130/86

APPENDIX 10

ENERGY EXPENDED BY MALES DURING PROFILE MILLING AT THE START OF THE STUDY

Anaemic group	
Number	Energy expended in Kilocalorie/mt
1	4.372
2	4.189
3	3.672
4	4.086
5	4.565
6	4.297

ENERGY EXPENDED BY MALES DURING MATCH LAPPING AT THE START OF THE STUDY

Anaemic group		Non Anaemic group	
Number	Energy expended in Kilocalorie/mt	Number	Energy expended in Kilocalorie/mt
1	3.839	1	3.479
2	4.337	2	3.184
3	3.657		
4	4.172		
5	3.864		
6	3.698		

ENERGY EXPENDED BY MALES DURING ROUGH LAPPING AT THE START OF THE STUDY

Anaemic group		Non Anaemic group	
Number	Energy expended in Kilocalorie/mt	Number	Energy expended in Kilocalorie/mt
1	4.056	1	3.165
2	3.898	2	2.891
3	3.801		
4	3.552		
5	4.197		
6	4.095		

ENERGY EXPENDED BY FEMALES IN SLOT MILLING AT THE START OF THE STUDY

Anaemic group	
Number	Energy expended in Kilocalorie/mt
1	4.179
2	4.165
3	4.198
4	4.165
5	3.856
6	4.182
7	4.164
8	3.875
9	4.476

ENERGY EXPENDED BY FEMALES DURING LAPPING AT THE START OF THE STUDY

Anaemic group

Number	Energy expended in Kilocalorie/mt
1	3.565
2	3.824
3	3.655
4	3.534
5	3.471
6	3.499
7	3.628
8	3.573
9	3.429
10	3.864

ENERGY EXPENDED IN PREPARING A FURROW BY ADOLESCENT BOYS AT THE START OF THE STUDY

Anaemic group		Non Anaemic group	
Number	Energy expended in Kilocalorie /mt	Number	Energy expended in Kilocalorie /mt
1	4.067	1	3.872
2	4.289	2	3.885
3	4.172	3	3.857
4	4.004	4	3.754
5	4.061	5	3.678
6	4.349	6	3.888
7	4.207	7	3.816
8	4.392	8	3.809
9	3.904	9	3.862
10	3.763	10	3.697
11	4.075	11	3.746
12	4.132	12	3.856
13	3.987	13	3.729
14	4.268	14	3,841
15	3.967	15	3.875
16	4.125	16	3.662
17	4.061		
18	4.264		
19	3.996		

Anaemic group	
Number	Energy expended in Kilocalorie / mt
20	4.425
21	4.271
22	4.121
23	4.361
24	4.072
25	4.262
26	4.125
27	4.071
28	3.954
29	3.955
30	3.772
31	3.948
32	4.061
33	4.197
34	4.101
35	4.099
36	4.196
37	4.225
38	4.314

APPENDIX 11

WORK OUTPUT IN TERMS OF THE NUMBER OF PIECES MILLED (PROFILE MILLING). AT THE START OF THE STUDY

Anaemic group	
Number	Piece output
1	258
2	265
3	270
4	310
5	306
6	250

WORK OUTPUT IN TERMS OF THE NUMBER OF PIECES LAPPED(MATCH LAPPING)AT THE START OF THE STUDY

Anaemic group		Non Anaemic group	
Number	Piece output	Number	piece output
1	106	1	132
2	80	2	124
3	116		
4	94		
5	116		
6	117		

WORK OUTPUT IN TERMS OF THE NUMBER OF PIECES LAPPED (ROUGH LAPPING) AT THE START OF THE STUDY

Anaemic group		Non Anaemic group	
Number	Piece output	Number	Piece output
1	152	1	215
2	174	2	229
3	162		
4	208		
5	143		
6	156		

WORK OUTPUT IN TERMS OF NUMBER OF PIECES MILLED (SLOT MILLING) AT THE START OF THE STUDY

Anaemic group	
Number	Piece output
1	950
2	1157
3	1000
4	1062
5	1200
6	1225
7	1170
8	1060
9	1082

WORK OUTPUT IN TERMS OF THE NUMBER OF PIECES LAPPED AT THE START OF THE STUDY

Anaemic group	
Number	Piece output
1	22
2	15
3	21
4	25
5	27
6	24
7	21
8	22
9	21
10	14

WORK OUTPUT INTERMS OF LENGTH COVERED IN PREPARING
FURROWS BY ADOLESCENT BOYS
AT THE START OF THE STUDY.

Anaemic group		Non Anaemic group	
Number	Length covered in feet	Number	Length covered in feet
1	38	1	52
2	30	2	53
3	36	3	50
4	29	4	55
5	36	5	60
6	29	6	52
7	32	7	49
8	33	8	51
9	34	9	56
10	42	10	64
11	38	11	52
12	34	12	53
13	40	13	55
14	32	14	51
15	40	15	50
16	34	16	64
17	40		
18	32		
19	38		

Anaemic group	
Number	Length covered in feet
20	35
21	33
22	34
23	29
24	33
25	30
26	32
27	38
28	34
29	33
30	45
31	38
32	42
33	38
34	34
35	32
36	30
37	38
38	29

APPENDIX 12

INDIVIDUAL PULSE RATE DURING ERGOMETRY AT THE START OF THE STUDY

Males			Females		
Number	Before activity	After activity	Number	Before activity	After activity
1	79	152	1	79	148
2	77	149	2	79	149
3	73	138	3	81	154
4	75	142	4	79	150
5	80	155	5	75	145
6	78	150	6	78	147
			7	79	150
			8	77	146
			9	81	154

APPENDIX

INDIVIDUAL PULSE RATE DURING ERGOMETRY AT THE START OF THE STUDY IN ADOLESCENT BOYS

Anaemic			Non Anaemic		
Number	Before activity	After Activity	Number	Before activity	After activity
1	74	140	1	77	142
2	79	152	2	75	143
3	75	142	3	78	145
4	79	154	4	76	140
5	75	143	5	74	135
6	79	152	6	75	144
7	77	148	7	79	148
8	76	145	8	77	143
9	75	143	9	75	138
10	72	135	10	73	132
11	74	140	11	75	142
12	75	147	12	75	143
13	75	137	13	76	140
14	77	144	14	75	142
15	73	136	15	78	145
16	77	146	16	72	130
17	73	138			
18	77	148			
19	74	140			

Anaemic		
Number	Before activity	After activity
20	75	142
21	77	147
22	77	147
23	76	140
24	76	140
25	73	130
26	73	133
27	72	130
28	75	133
29	73	134
30	71	127
31	71	133
32	71	126
33	72	130
34	73	133
35	73	134
36	75	138
37	73	134
38	76	146

TIME REQUIRED FOR EXHAUSTION ON AN ERGOMETER AT THE START OF THE STUDY

Men		Women	
Number	Time in Seconds	Number	Time in Seconds
1	70	1	50
2	90	2	55
3	130	3	70
4	105	4	75
5	60	5	80
6	80	6	75
		7	70
		8	90
		9	50

TIME REQUIRED FOR EXHAUSTION ON AN ERGOMETER AT THE START OF THE STUDY IN ADOLESCENT BOYS.

Anaemic		Non anaemics	
Number	Time in Seconds	Number	Time in Seconds
1	120	1	120
2	70	2	115
3	110	3	100
4	65	4	120
5	115	5	140
6	70	6	115
7	90	7	105
8	95	8	110
9	100	9	120
10	140	10	135
11	120	11	115
12	95	12	120
13	135	13	110
14	90	14	115
15	130	15	100
16	95	16	155
17	130		
18	90		
19	120		

Anaemics		[illegible]	
Number	Time in seconds	[illegible]	[illegible]
20	100		
21	90		
22	85		
23	60		
24	95		
25	70		
26	95		
27	120		
28	100		
29	95		
30	150		
31	120		
32	140		
33	115		
34	80		
35	95		
36	65		
37	120		
38	60		

INDIVIDUAL SERUM IRON VALUES AFTER SUPPLEMENTATION IN ADOLESCENT BOYS

Number	Serum iron µg/100 ml
1	75
2	74
3	70
4	71
5	80
6	65
7	66
8	73
9	78
10	80
11	71
12	69
13	74
14	72
15	75
16	76
17	81
18	68
19	73

INDIVIDUAL SERUM IRON VALUES AFTER SUPPLEMENTATION IN ADOLESCENT BOYS

Number	Serum iron µg/100 ml
1	75
2	74
3	70
4	71
5	80
6	65
7	66
8	73
9	78
10	80
11	71
12	69
13	74
14	72
15	78
16	76
17	81
18	69
19	73

Number	Serum iron μg/100 ml
20	77
21	66
22	69
23	75
24	72
25	80
26	72
27	79
28	73
29	63
30	84
31	84
32	89
33	88
34	74
35	75
36	79
37	78
38	69

APPENDIX 14

INDIVIDUAL HAEMOGLOBIN VALUES AFTER SUPPLEMENTATION

Males		Females	
Number	Haemoglobin g/100ml	Number	Haemoglobin g/100ml
1	12.9	1	12.1
2	13.2	2	12.2
3	13.7	3	11.8
4	13.4	4	11.9
5	12.7	5	12.5
6	12.8	6	12.1
7	13.2	7	11.7
8	12.4	8	12.6
9	13.5	9	12.0
10	12.9	10	12.0
11	13.6	11	11.3
12	13.4	12	11.8
13	12.8	13	12.0
14	13.9	14	12.3
15	13.2	15	11.2
16	14.0	16	11.9
17	13.2	17	11.8
18	13.0	18	11.9
		19	11.3

INDIVIDUAL HAEMOGLOBIN VALUES AFTER SUPPLE MENTATION
IN ADOLESCENT BOYS

N umber	Haemoglobin g/100ml
1	14.0
2	13.0
3	13.4
4	12.9
5	13.5
6	13.2
7	13.5
8	12.8
9	13.2
10	14.0
11	13.8
12	12.9
13	13.6
14	12.5
15	13.6
16	12.7
17	13.5
18	14.0
19	13.8

Number	Haemoglobin g/100 ml
20	13.4
21	12.9
22	13.6
23	13.0
24	13.9
25	13.2
26	13.9
27	13.9
28	13.2
29	13.7
30	14.4
31	13.8
32	14.1
33	14.0
34	13.6
35	13.7
36	13.2
37	13.7
38	13.0

APPENDIX 15

INDIVIDUAL PULSE RATE IN MALES PERFORMING PROFILE MILLING AFTER SUPPLE MENTATION

Number	Before activity	After activity
1	79	115
2	75	113
3	75	111
4	77	114
5	79	115
6	80	116

INDIVIDUAL PULSE RATE IN MALES AFTER SUPPLEMENTATION

Match Lapping			Rough Lapping		
Number	Before activity	After activity	Number	Before activity	After activity
1	78	112	1	79	111
2	80	114	2	75	107
3	76	110	3	77	109
4	79	113	4	74	106
5	75	109	5	77	109
6	77	111	6	78	110

INDIVIDUAL PULSE RATE IN FEMALES AFTER SUPPLEMENTATION

Slot milling			Lapping		
Number	Before activity	After activity	Number	Before activity	After activity
1	82	120	1	79	110
2	81	121	2	79	110
3	82	122	3	80	109
4	82	122	4	79	110
5	79	120	5	78	108
6	82	121	6	77	110
7	82	123	7	79	111
8	79	120	8	75	109
9	79	120	9	75	109
			10	78	109

INDIVIDUAL PULSE RATE IN ADOLE[illegible]
SUPPLEMENTATION

Number	Before activity	After activity
1	71	119
2	75	123
3	74	120
4	76	123
5	73	120
6	74	122
7	73	121
8	76	124
9	74	122
10	71	119
11	72	119
12	76	126
13	72	120
14	77	125
15	72	120
16	76	124
17	73	121
18	71	119
19	72	120

Number	Before activity	After activity
20	72	122
21	75	120
22	72	123
23	75	119
24	71	119
25	74	122
26	71	119
27	72	120
28	74	122
29	72	120
30	71	118
31	72	120
32	70	119
33	71	119
34	73	120
35	72	120
36	74	119
37	70	119
38	75	123

APPENDIX 16

INDIVIDUAL BLOOD PRESSURE IN MALES AFTER SUPPLEMENTATION

Number	Profile milling	
	Before activity	After activity
1	120/80	130/90
2	115/75	130/82
3	120/90	130/84
4	122/82	130/82
5	124/78	130/90
6	115/80	128/80

INDIVIDUAL BLOOD PRESSURE [illegible]

	Match lapping			Rough lapping	
Number	Before activity	After activity	Number	Before activity	After activity
1	120/90	128/90	1	120/75	130/84
2	120/80	128/82	2	120/75	132/90
3	125/95	130/90	3	115/90	130/80
4	128/90	130/80	4	120/80	130/86
5	122/82	132/82	5	122/76	130/80
6	124/78	130/84	6	115/80	132/85

INDIVIDUAL BLOOD PRESSURE IN FEMALES AFTER SUPPLEMENTATION

	Slot milling			Lapping	
Number	Before activity	after activity	Number	Before activity	After activity
1	116/78	126/86	1	115/75	122/84
2	120/80	124/85	2	120/80	135/80
3	124/78	124/82	3	122/75	132/84
4	115/75	130/84	4	120/70	132/82
5	120/70	120/86	5	120/72	132/85
6	118/[illegible]	126/82	6	116/75	125/80
7	128/78	126/80	7	120/75	130/84
8	120/50	110/88	8	110/80	128/84
9	115/75	124/82	9	120/80	128/90
			10	122/82	130/80

INDIVIDUAL BLOOD PRESSURE OF THE ADOLESCENT BOYS AFTER SUPPLEMENTATION

Number	Before activity	After activity
1	115/80	132/82
2	120/80	130/80
3	120/80	130/80
4	120/90	130/80
5	122/82	132/80
6	120/80	130/80
7	124/78	130/80
8	120/80	130/80
9	120/80	132/82
10	122/82	132/82
11	124/76	132/80
12	122/77	132/78
13	120/80	132/78
14	115/70	130/80
15	115/80	132/82
16	120/80	130/80
17	122/80	130/82
18	124/84	132/82
19	122/84	130/80

Number	Before activity	After activity
20	120/80	128/80
21	124/80	130/80
22	120/92	128/82
23	120/80	130/80
24	110/80	132/82
25	120/80	130/80
26	118/82	132/80
27	118/80	132/80
28	118/72	130/80
29	120/82	130/80
30	115/75	134/84
31	115/80	132/84
32	120/90	134/82
33	115/78	132/82
34	120/80	126/84
35	115/95	130/80
36	120/90	130/80
37	120/75	132/82
38	115/80	130/80

APPENDIX 17

ENERGY EXPENDED IN KILO CALORIE/MINUTE AFTER SUPPLEMENTATION IN MALES

Number	Profile milling	Number	Match lapping
1	3.672	1	3.365
2	3.498	2	3.774
3	3.165	3	3.190
4	3.487	4	3.398
5	3.687	5	2.954
6	3.652	6	3.057

Number	Rough lapping
1	3.375
2	2.694
3	3.162
4	2.741
5	3.156
6	3.257

ENERGY EXPENDED IN KILO CALORIE / MINUTE AFTER SUPPLEMENTATION IN FEMALES

Number	Slot Milling	Number	lapping
1	3.574	1	3.088
2	3.656	2	3.405
3	3.692	3	3.174
4	3.678	4	3.089
5	3.256	5	2.895
6	3.436	6	3.479
7	3.674	7	3.094
8	3.175	8	3.168
9	3.583	9	3.152
		10	3.456

ENERGY EXPENDED IN KILO CALORIE IN ADOLESCENT BOYS AFTER SUPPLEMENTATION

Number	Preparing furrows	Number	Preparing furrows
1	3.668	20	3.701
2	3.842	21	3.714
3	3.894	22	3.692
4	3.755	23	3.787
5	3.625	24	3.693
6	3.699	25	3.685
7	3.787	26	3.104
8	3.645	27	3.582
9	3.764	28	3.553
10	3.551	29	3.669
11	3.667	30	3.490
12	3.809	31	3.596
13	3.968	32	3.148
14	3.642	33	3.662
15	3.677	34	3.884
16	3.881	35	3.674
17	3.697	36	3.625
18	3.597	37	3.584
19	3.886	38	3.757

APPENDIX 18

ENERGY EXPENDED BY MALES ON AN ERGOMETER BEFORE AND AFTER SUPPLEMENTATION

Energy Expressed in Kilo calories		
Anaemic Group		
Number	Before Supplementation	After Supplementation
1	5.478	4.932
2	5.192	4.674
3	4.672	4.381
4	4.959	4.688
5	5.576	4.975
6	5.254	4.768

ENERGY EXPENDED BY WOMEN ON AN ERGOMETER BEFORE AND AFTER SUPPLEMENTATION

Energy Expended in Kilo calories

Anaemic Group

Number	Before Supplementation	After Supplementation
1	5.154	4.699
2	5.174	4.615
3	5.198	4.975
4	5.547	4.841
5	4.658	4.575
6	4.955	4.709
7	5.171	4.945
8	4.871	4.467
9	5.564	4.754

ENERGY EXPENDED BY ADOLESCENT BOYS ON AN ERGOMETER BEFORE AND AFTER IRON SUPPLEMENTATION

Energy Expressed in Kilo Calories / mt.

Anaemic group

Number	Before Supplementation	Number	After Supplementation
1	4.756	1	4.281
2	5.378	2	4.795
3	4.864	3	4.690
4	5.573	4	4.974
5	5.159	5	4.574
6	5.562	6	4.654
7	5.198	7	4.564
8	5.189	8	4.872
9	5.017	9	4.679
10	4.546	10	4.237
11	4.772	11	4.498
12	5.127	12	4.998
13	4.659	13	4.463
14	5.175	14	5.064
15	4.625	15	4.472
16	5.141	16	4.854
17	4.869	17	4.573
18	5.174	18	4.283
19	4.745	19	4.372

ANAEMIC GROUP

Number	Energy expended in Kilo Calorie/mt	Number	Energy expended in kilo calorie/mt.
20	4.928	20	4.654
21	5.178	21	4.879
22	5.194	22	4.358
23	5.468	23	4.769
24	5.181	24	4.207
25	5.485	25	4.601
26	5.342	26	4.437
27	4.775	27	4.451
28	5.075	28	4.672
29	5.184	29	4.449
30	4.269	30	4.068
31	4.765	31	4.475
32	4.574	32	4.256
33	4.987	33	4.201
34	5.192	34	4.429
35	5.449	35	4.327
36	5.348	36	4.668
37	4.767	37	4.456
38	5.496	38	4.782

INDIVIDUAL PULSE RATE DURING ERGOMETRY AFTER SUPPLEMENTATION

Males			Females		
Number	Before activity	After Activity	Number	Before Activity	After Activity
1	75	142	1	74	144
2	73	138	2	73	144
3	73	136	3	76	150
4	75	138	4	72	145
5	77	143	5	72	145
6	75	143	6	73	148
			7	75	145
			8	70	143
			9	74	146

INDIVIDUAL PULSE RATE DURING ERGOMETRY AFTER SUPPLEMENTATION IN ADOLESCENT BOYS

Number	Before Activity	After Activity
1	70	130
2	76	140
3	75	134
4	76	140
5	74	135
6	75	136
7	74	135
8	77	143
9	75	139
10	75	138
11	75	138
12	76	140
73	73	132
14	74	145
15	76	140
16	77	144
17	74	135
18	76	140
19	72	130

Number	Before activity	After Activity
20	73	133
21	76	140
22	73	133
23	76	140
24	76	140
25	73	139
26	73	133
27	72	130
28	75	133
29	73	134
30	71	127
31	71	133
32	71	126
33	72	130
34	73	133
35	73	134
36	75	138
37	73	134
38	76	140

TIME REQUIRED FOR EXHAUSTION ON AN ERGOMETER AFTER SUPPLEMENTATION

Men		Women	
Number	Time in Seconds	Number	Time in seconds
1	120	1	75
2	125	2	80
3	145	3	70
4	115	4	75
5	110	5	90
6	115	6	80
		7	75
		8	100
		9	90

TIME REQUIRED FOR EXHAUSTION ON AN ERGOMETER AFTER SUPPLEMENTATION IN ADOLESCENT BOYS

Number	Time in Seconds	Number	Time in seconds
1	160	20	125
2	120	21	120
3	135	22	150
4	115	23	120
5	140	24	155
6	130	25	130
7	140	26	150
8	120	27	155
9	130	28	130
10	160	29	150
11	155	30	170
12	115	31	155
13	150	32	165
14	100	33	160
15	145	34	145
16	120	35	150
17	140	36	130
18	160	37	140
19	155	38	120

APPENDIX 19

WORK OUTPUT IN TERMS OF NUMBER OF PIECES IN MALES AFTER SUPPLEMENTATION

Number	Profile Milling
1	322
2	346
3	365
4	380
5	373
6	314

Number	Match lapping
1	144
2	127
3	137
4	140
5	148
6	152

Number	Rough Lapping
1	230
2	251
3	220
4	282
5	213
6	226

WORK OUTPUT IN TERMS OF NUMBER OF PIECES IN FEMALES AFTER SUPPLEMENTATION

Number	Slot milling
1	1070
2	1175
3	1200
4	1187
5	1300
6	1340
7	1244
8	1144
9	1216

Number	Lapping
1	30
2	24
3	35
4	30
5	37
6	34
7	35
8	33
9	35
10	22

WORK OUTPUT IN TERMS OF LENGTH COVERED IN PREPARING FURROWS BY ADOLESCENT BOYS AFTER SUPPLEMENTATION

Number	Length covered in feet	Number	Length covered in feet
1	65	20	58
2	55	21	54
3	59	22	61
4	53	23	60
5	60	24	64
6	58	25	58
7	60	26	64
8	53	27	63
9	58	28	58
10	65	29	62
11	62	30	69
12	54	31	63
13	61	32	66
14	50	33	65
15	62	34	61
16	53	35	63
17	60	36	58
18	65	37	64
19	63	38	55