RESULTS AND DISCUSSION

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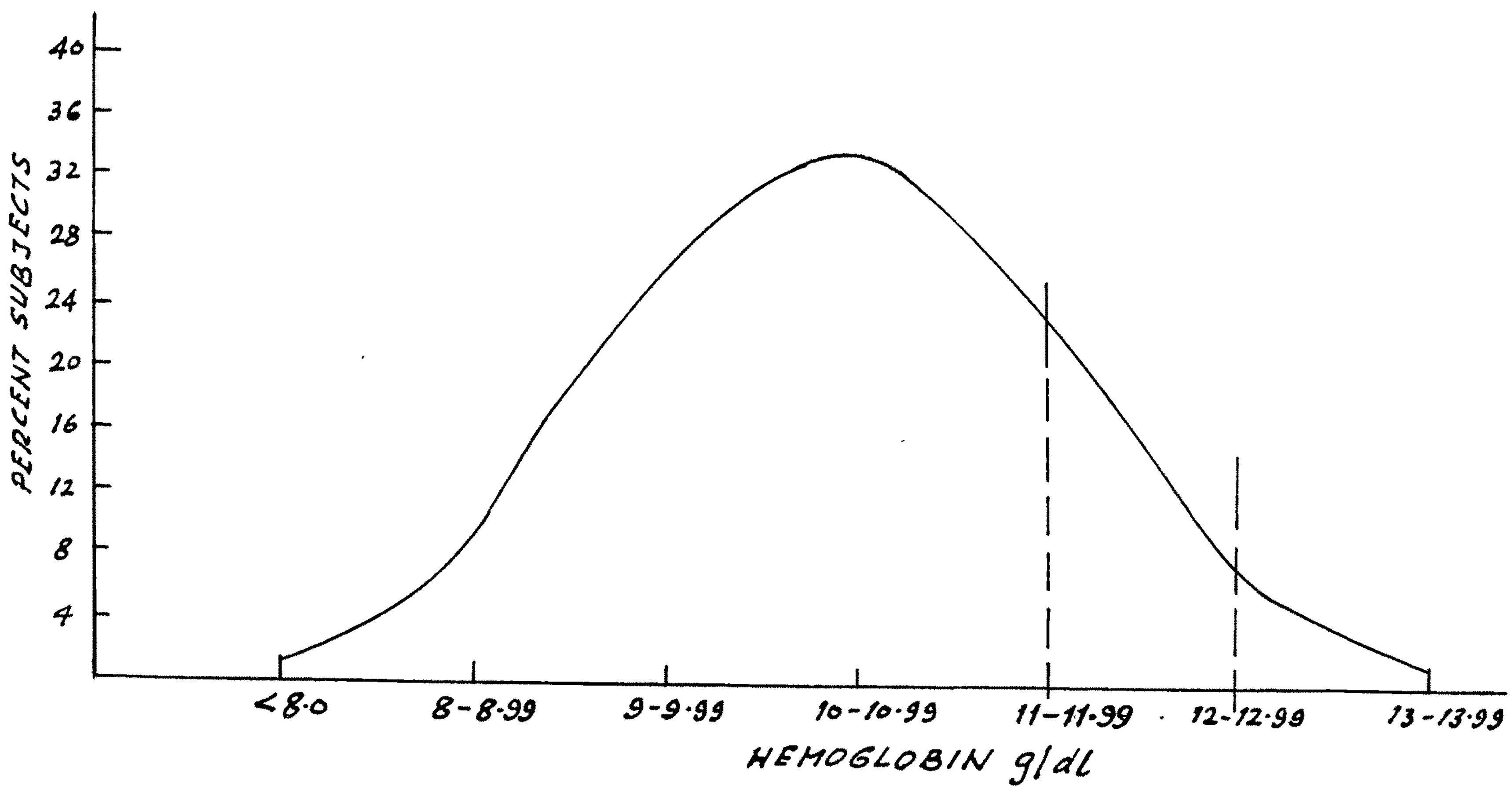
The purpose of the present study was to evaluate the impact of iron supplementation at a dose level of 60 mg elemental Fe per day for 60 days, twice in a school year on the iron status and selected functional areas, namely, cognitive function (CF), physical work capacity (PWC) and growth on underprivileged school girls, 8-15 years old.

In accordance with the specific objectives of the present study the results are presented and discussed under the following sections :

I. Iron status of the study population -
   1. Prevalence of anemia.
   2. Impact of Fe supplementation on the Hb status.
   3. Impact of Fe supplementation on Fe status.

II. Impact of Fe supplementation on Cognitive Function (CF) tests -
   1. Impact of supplementation on the CF test scores of the total study population.
   2. Relationship between the measures of iron status and CF test scores.
   3. Impact of supplementation on the anemic and non-anemic subjects in CF test scores.

FIG. 6 FREQUENCY DISTRIBUTION OF Hb VALUES OF THE UNDERPRIVILEGED SCHOOL GIRLS (8-15 YRS. OF AGE) AT BASELINE



4. Impact of supplementation on CF test scores in younger and older subjects.

III. Impact of iron supplementation on Physical Work Capacity (PWC) -

1. Impact of iron supplementation on selected parameters of PWC in underprivileged school girls.
2. Relationship between measures of Fe status and PWC.
3. Impact of Fe supplementation on anemic and non-anemic subjects.
4. Impact of Fe supplementation on younger and older school girls.

IV. Impact of iron supplementation on growth.

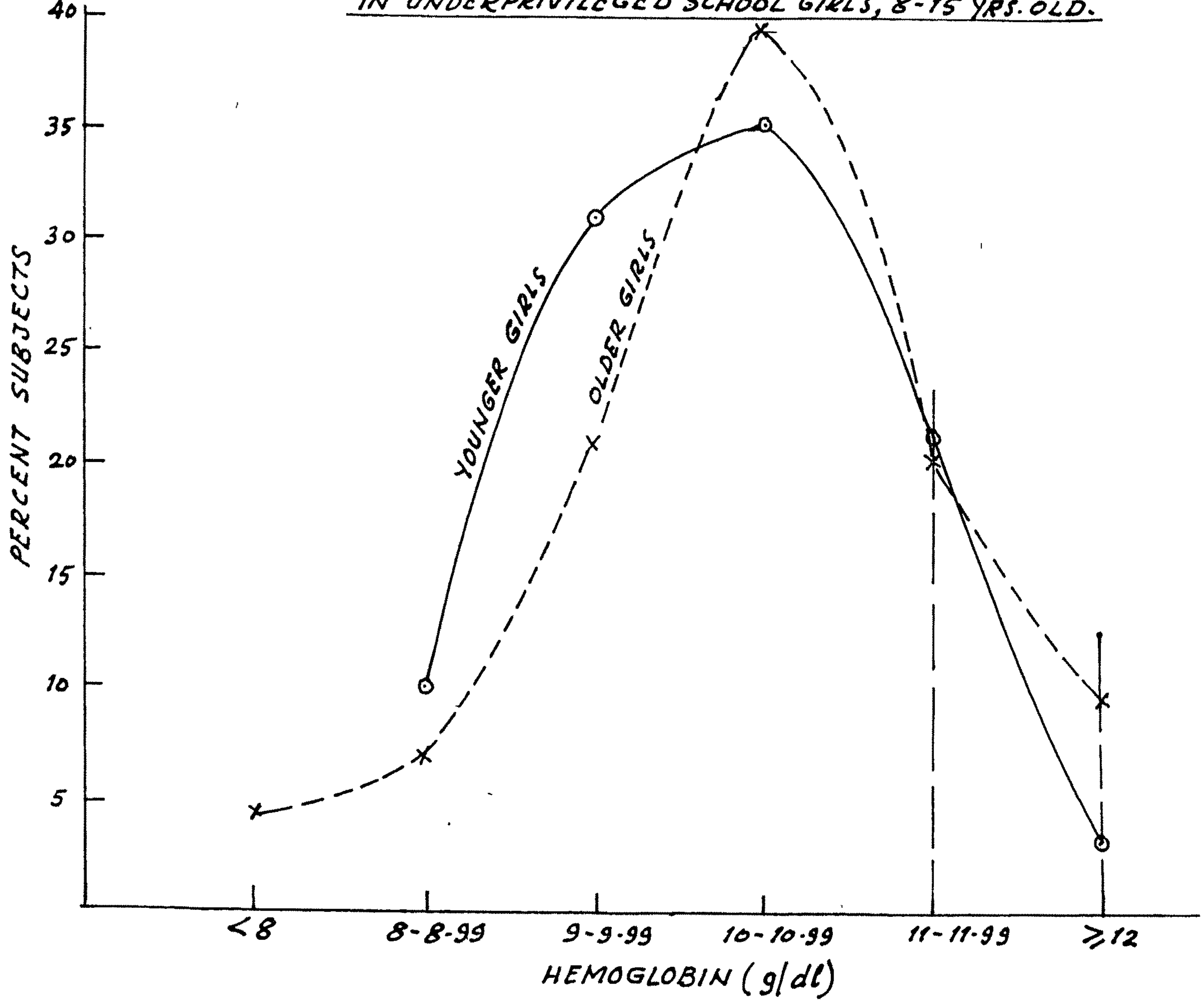
I. Iron status of the study population

1. Prevalence of anemia

The prevalence of anemia was near universal (90%) using the WHO norm of Hb $\angle$ 12 g/dl. Even, using the more modest cut off point, suggested by Singla and Agarwal (1981) for anemia, in Indian school age children, as Hb $\angle$ 11 g/dl, nearly three-quarters (70%) of the subjects were found to be anemic, which is certainly a disturbing picture.

The frequency distribution of Hb values (Fig. 6) revealed a marked skewness of the curve to the left of the cut off point of

FIG. 7 DISTRIBUTION CURVES FOR Hb VALUES AT BASELINE FOR THE TWO AGE CATEGORIES (AGE < 11 YEARS & ≥ 11 YEARS) IN UNDERPRIVILEGED SCHOOL GIRLS, 8-15 YRS. OLD.



12 g/dl. Further, a large proportion of the sample was to the left of the cut off point of 11 g/dl. The peak of the curve in the study population was seen between Hb values of 10 - 10.99 g/dl.

On classifying the data into two age categories, namely,

1. Younger girls, less than 11 years of age, and
2. Older girls, equal to or greater than 11 years of age,

a very large segment of the subjects in each category were anemic using either cut off points (Fig.7). Also, no major difference was observed in the prevalence figures between the younger and older girls.

Table 7 gives the actual prevalence figures for the two age categories using either cut off points.

Table 7. Percent prevalence of anemia in younger (age $\angle$ 11 yrs) and older (age $\geqslant$ 11 yrs) girls, 8 - 15 yrs of age.

Age categories	Hb $\angle$ 11 g/dl	Hb $\angle$ 12 g/dl
Younger girls age $\angle$ 11 yrs (118)	69 (81)	92 (109)
Older girls age $\geqslant$ 11 yrs (48)	73 (35)	92 (44)
χ^2 value		0.0176

Figures in parentheses indicate actual number of subjects.

Results of the RCM examination are represented in Table 8. The RCM examination was done on these subjects to identify the major cause of anemia. A predominantly microcytic hypochromic picture indicated that anemia was primarily due to iron deficiency. A total lack of macrocytic megaloblastic red cell picture indicated the absence of folic acid deficiency.

Table 8. Red Cell Morphology of under privileged school girls (8-15 yrs) at baseline evaluation

Red cell picture		% prevalence
Hypochromic microcytic	...	81.31 (135)
Hypochromic anisocytic	...	13.25 (22)
Normocytic hypochromic	...	5.42 (9)

Figure in parentheses indicate actual number of subjects.

2. Impact of Fe supplementation on Hb status

Having established that iron deficiency was the chief cause of anemia, the effect of 60 mg elemental Fe per day, administered for 60 days, twice in a school year was evaluated. The study was designed such that the impact of inputs could be studied during intervention as well as 4 months after withdrawal of supplements.

Table 9. Impact of intervention on the prevalence of anemia in underprivileged school girls, 8 - 15 yrs of age.

Groups	Cut off point taken as $\angle$ 11 g/dl % Prevalence				Cut off point taken as $\angle$ 12 g/dl % Prevalence			
	Baseline	Mid	Final	Post-final	Baseline	Mid	Final	Post-final
Iron treated group	70 (58)	25 (21)	1 (1)	58 (48)	90 (75)	59 (49)	31 (26)	89 (74)
Placebo group	70 (58)	54 (45)	57 (47)	73 (61)	95 (79)	89 (74)	92 (76)	94 (78)

Note : Figures in parentheses indicate actual number of subjects.

FIG. 8 CHANGES IN Hb VALUES OVER ONE YEAR ON Fe SUPPLEMENTATION IN UNDERPRIVILEGED SCHOOL GIRLS 8-15 YEARS OF AGE

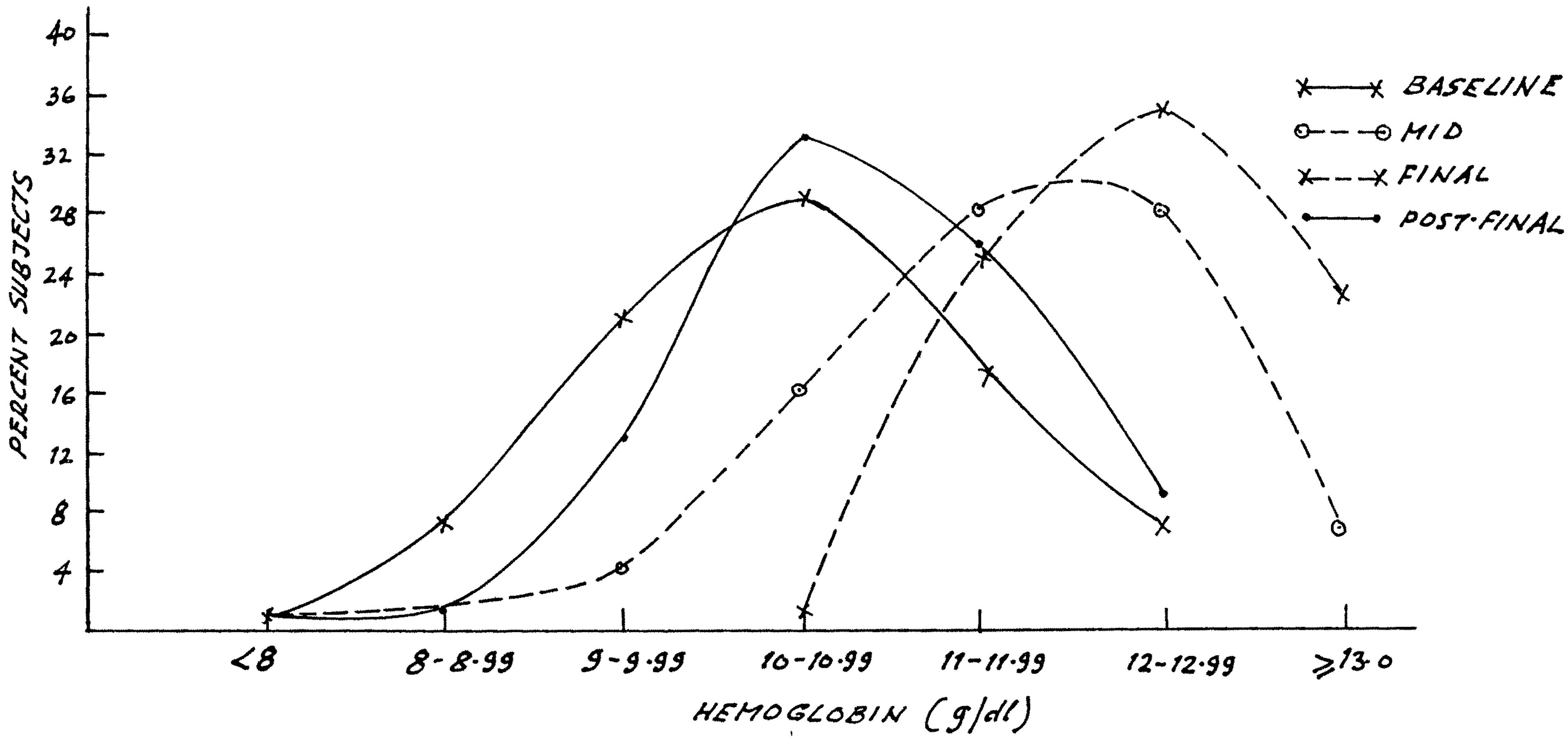


FIG. 9 CHANGES IN Hb VALUES OVER ONE YEAR IN THE PLACEBO GROUP OF UNDERPRIVILEGED SCHOOL GIRLS, 8-15 YRS. OF AGE.

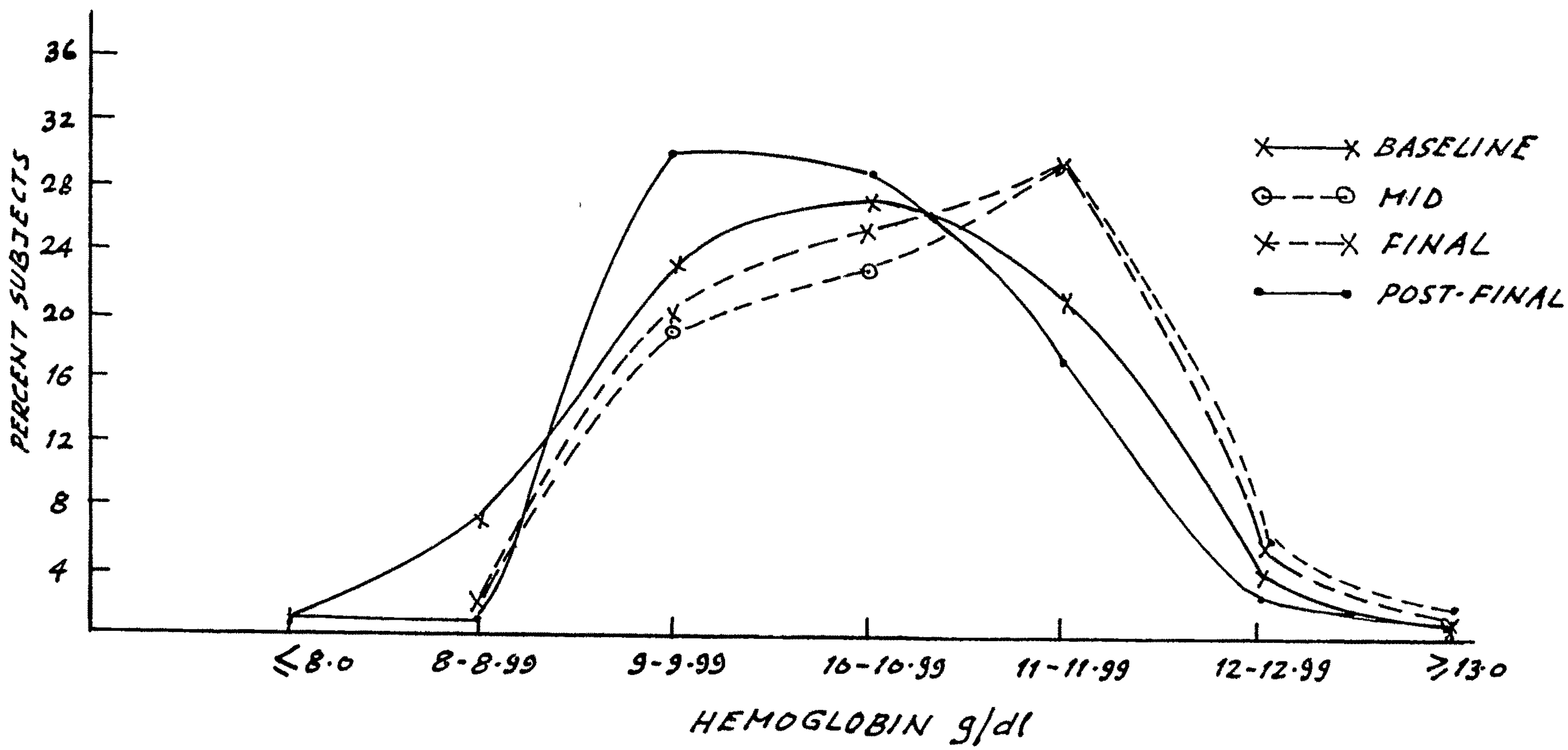
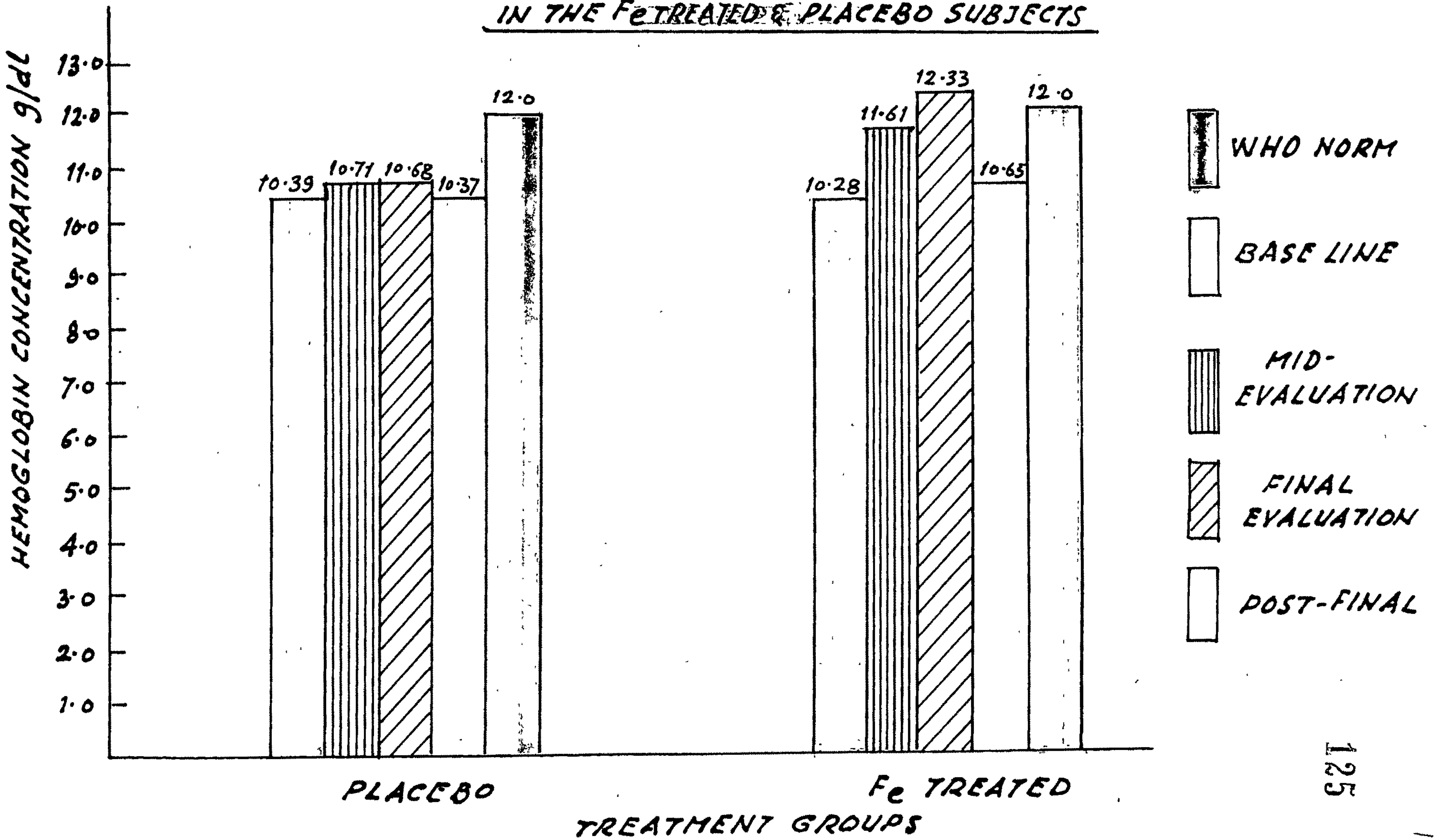


FIG.10 COMPARISON OF Hb LEVEL BEFORE AND AFTER SUPPLEMENTATION OVER 1 YEAR WITH WHO STANDARD IN THE Fe TREATED & PLACEBO SUBJECTS



12

(a) Response to supplementation on the prevalence of anemia

Hemoglobin estimates made every 4 months over a period of 1 year indicated a drastic reduction in the prevalence of anemia in the iron treated group.

Table 9 indicates a drop in the prevalence of anemia by 64% i.e. from 75 to 25%, at 4 months and a further reduction of 96%, from 25 to 1%, at 8 months using the 11 g/dl cut off point. This indicated that majority of the anemic cases were iron responsive. However, on withdrawal of Fe supplementation for a period of 4 months the picture reverted to nearly that at baseline.

Figure 8 indicates the changes in the Hb values for the iron treated subjects over 1 year. The figure clearly indicates a shift in Hb values from the lower to the higher ranges. Nearly 60% of the subjects had attained Hb values greater than 12 g/dl, indicating a reduction in the prevalence of anemia. The Hb values of the placebo group however, remained virtually stationary as depicted in Fig.9.

The mean Hb values at each point of time in either of the groups (Fe treated and placebo) were compared to the WHO norm of 12 g/dl. As indicated in Fig. 10, the mean Hb values of the Fe treated group increased steadily on intervention and was greater than the WHO norm at final evaluation. However, no change in the Hb values for the placebo group were evident.

Table 10. Increments in Hb values in the Fe supplemented group from Baseline to Final evaluation

Increments from Baseline	< 0.5 g/dl	0.5-1.0 g/dl	1.0-2.0 g/dl	> 2.0 g/dl
Mid evaluation	15 (10)	26 (17)	38 (25)	20 (13)
Final evaluation	3 (2)	3 (2)	46 (30)	48 (31)

Values represented as percentage.

Figures in parentheses indicate actual numbers.

Table 11. Changes in Hb status over one year study period in the Fe treated and placebo groups.

	Group I (Fe Treated)	Group II (Placebo)	Independent 't' values
Baseline (B)	10.28 ± 0.14	10.39 ± 0.14	0.5308 ^{NS}
Mid (M)	11.61 ± 0.14	10.71 ± 0.12	4.3876 ***
Final (F)	12.33 ± 0.09	10.68 ± 0.11	10.7831 ***
Post-Final (PF)	10.65 ± 0.12	10.37 ± 0.11	1.6734 ^{NS}
<u>Paired 't' values</u>			
B Vs M	12.25 ***	3.44 **	
B Vs F	16.95 ***	3.32 **	
B Vs PF	3.96 **	-0.34 ^{NS}	
M Vs F	7.78 ***	-0.63 **	
M Vs PF	-8.65 ***	-4.03 **	
F Vs PF	-15.32 ***	-3.94 **	

NS - Non significant difference between the two groups.

** - Difference between the two groups significant (P ∠ 0.01)

*** - Difference between the means of the two groups highly significant (p ∠ 0.001).

Table 10 indicates the response of Fe supplementation at 60 mg elemental Fe per day for 60 days (mid evaluation) and after the second 60 day intervention (final evaluation).

Based on dose response, 58% of the subjects had a dose response of ≥ 1 g/dl at mid intervention and more than 90% showed an improvement > 1 g/dl by the end of the 2nd intervention (final evaluation). These results supported the earlier contention that, anemia was primarily due to iron deficiency and iron deficiency anemia was near universal in this study population. It also showed that a response of ≥ 1 g/dl Hb, improved with the second dosing, with more than 90% of the study subjects registering this level of response.

(b) Changes in mean Hb levels

Table 11 indicates the impact of Fe treatment or placebo on the Hb status of the subjects over one school year.

1. Within group comparison -

The paired 't' test was used to compare each group over the entire study period (in columns). Comparisons were made as under :

1. Baseline (0 month) Vs Mid evaluation (4th month)
2. Baseline (B) Vs Final (8th month)

3. Baseline Vs Post-final (12th month)
4. Mid(M) Vs Final (F)
5. Mid Vs Post-final (PF)
6. Final Vs Post-final

Results indicated a highly significant ($p < 0.001$) improvement in the mean Hb values of the Fe treated group following each intervention. On withdrawal of Fe supplements, a significant ($p < 0.001$) drop in the mean Hb values from those at mid and final evaluation was observed. This value, however, was significantly higher than that at baseline. This indicated that the benefit of iron therapy was not totally lost, but was sustained at a level higher than the baseline value after the therapy was withdrawn for 4 months. The Hb values at baseline, mid, final and post-final evaluations were 10.28, 11.61, 12.33 and 10.65 g/dl respectively.

Marginal change (+ 0.32 g/dl) observed in the Hb values of the placebo group over the study period was statistically significant. The probable reason for this increase could be a variation in the dietary intake due to seasonal availability of certain foods, like fenugreek, amaranth, spinach etc.

2. Between group comparison

To compare the iron treated versus the placebo group, the independent 't' test was employed. Comparisons were made at Baseline, Mid, Final and Post-final evaluations.

The results of this analysis (Table 11, in rows) indicated that the two groups were similar to start with (at Baseline). Significantly higher Hb values ($p < 0.001$) were observed in the Fe treated group against the Placebo group at Mid (11.61 Vs 10.71 g/dl) and at Final (12.33 Vs 10.68 g/dl) evaluations. Hb values dropped significantly from the final values on withdrawal of Fe supplements, as a result, no difference was observed between the Fe treated and placebo group (10.65 Vs 10.37 g/dl) at Post-final evaluation.

Thus, a significant increase in Hb levels of subjects during Fe therapy and a decline after withdrawal of inputs clearly indicates the beneficial effect of intervention and the need for continued intervention every four months, to sustain the raised Hb levels.

3. <u>Impact of Fe supplementation on iron status</u>

The data on measures of iron status, namely, serum iron (SI), total iron binding capacity (TIBC) and transferrin saturation (TS) was collected on 102 subjects. The total sample included 48 Fe treated and 54 placebo subjects.

Table 12. Frequency distribution of Hb values in the Fe treated and Placebo group subjects at final evaluation

Hb range g/dl \ Treatment group	Iron treated (48)	Placebo group (54)
9.00 - 9.99	-	18.0 (10)
10.00 - 10.99	2.0 (1)	37.0 (20)
11.00 - 11.99	31.0 (15)	35.0 (19)
12.00 - 12.99	37.0 (18)	9.0 (5)
13.00 - 13.99	27.0 (13)	-
14.00 - 14.99	2.0 (1)	-

Figures in parenthesis indicate actual number of subjects

FIG. 11 Hb STATUS OF Fe TREATED VERSUS PLACEBO GROUP SUBJECTS AT FINAL EVALUATION

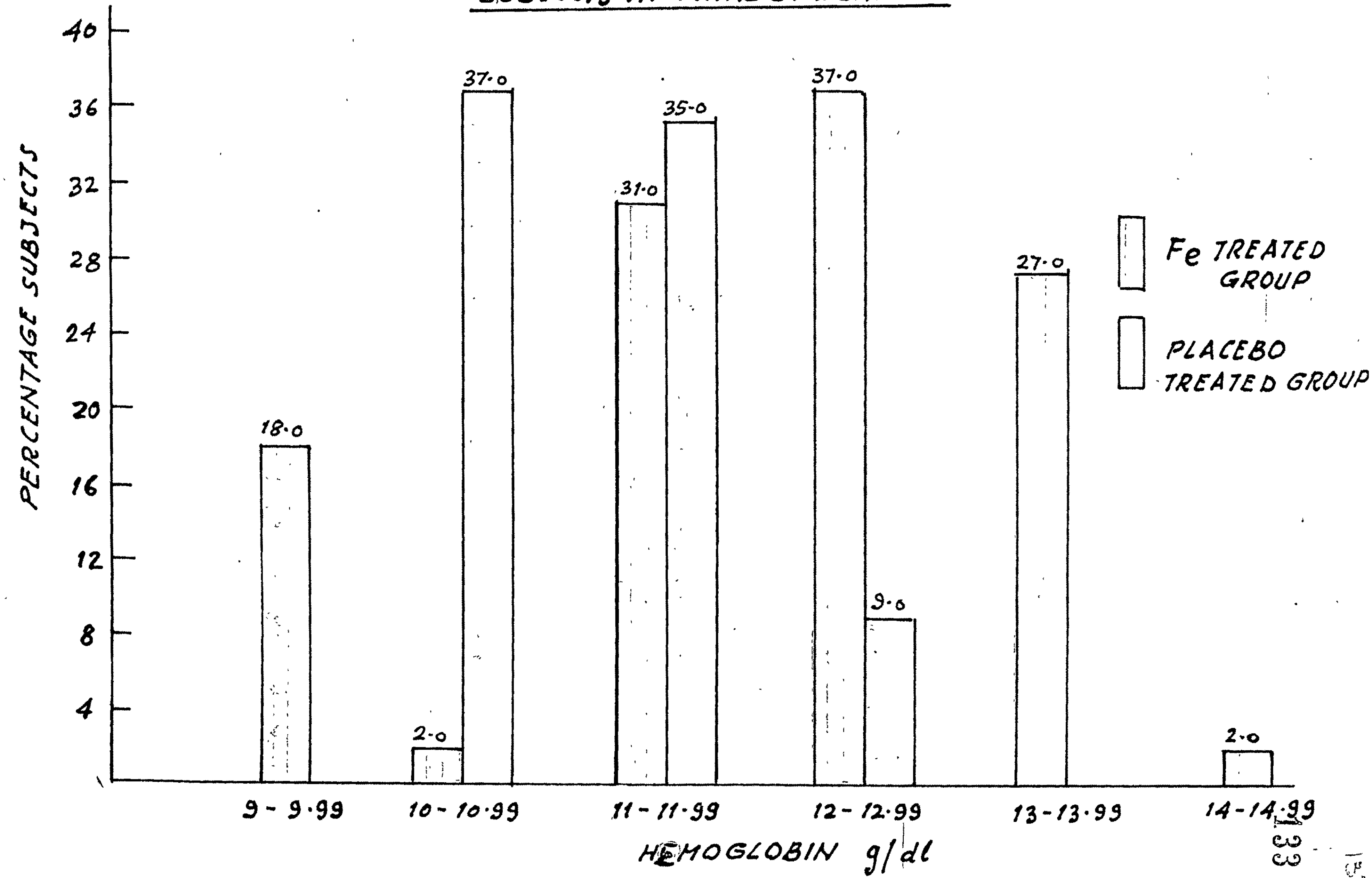


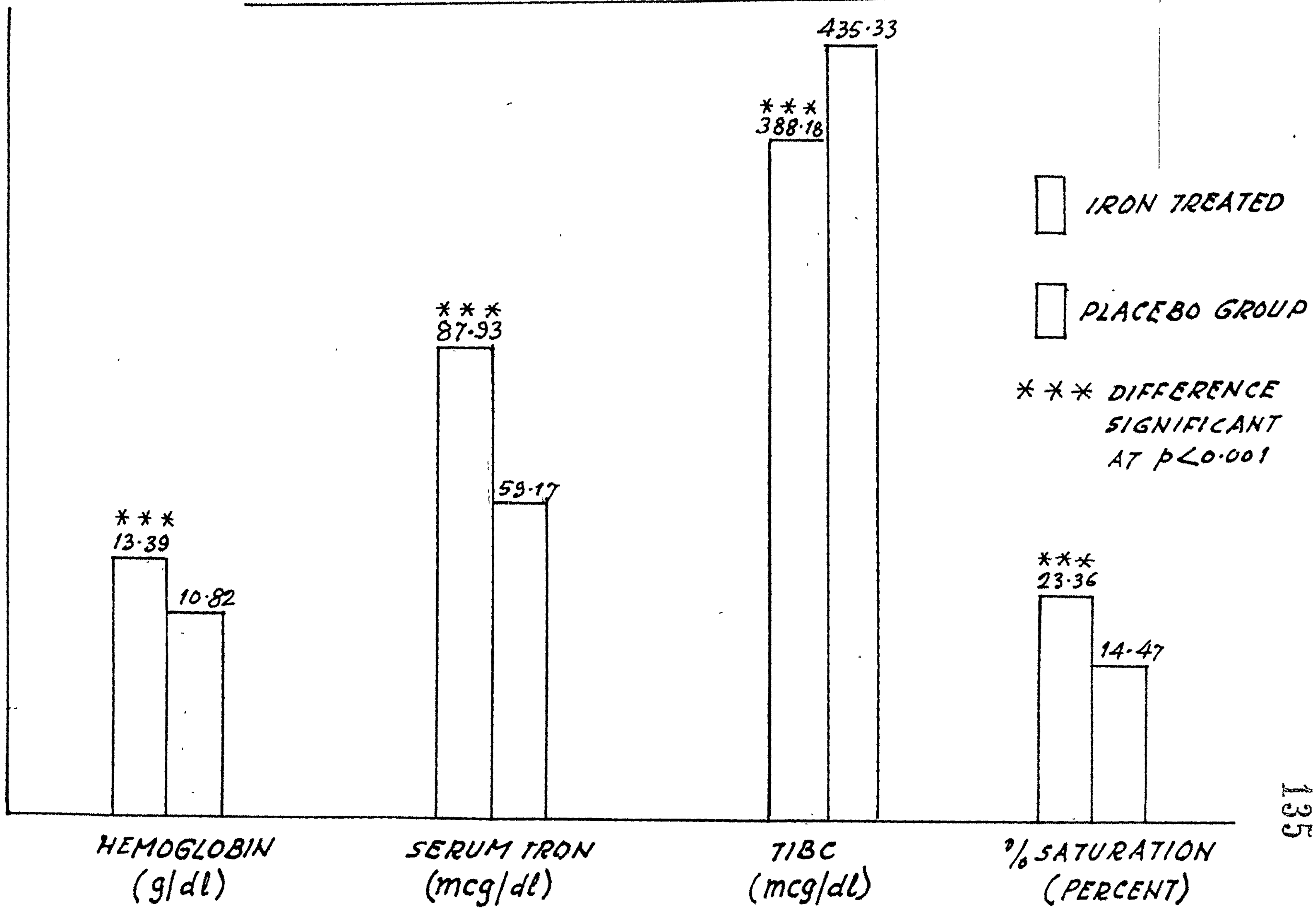
Table 13. Hematological status of iron treated versus placebo group after intervention for one school year.

Treatment groups	N	Hemoglobin (g/dl)	Serum iron (mcg/dl)	Total iron binding capacity (mcg/dl)	Percent saturation
Fe treated	48	13.39 $\pm$0.83	87.933 $\pm$3.644	388.034 $\pm$7.562	23.365 $\pm$1.262
Placebo	54	10.82 $\pm$0.91	59.178 $\pm$3.084	435.335 $\pm$8.277	14.476 $\pm$0.978
't' value		12.086***	5.052***	4.145***	4.614***

All values are mean $\pm$ SE.

*** Difference between values significant at $p < 0.001$.

FIG. 12 HEMATOLOGICAL STATUS OF Fe TREATED VERSUS PLACEBO GROUP AFTER INTERVENTION FOR ONE SCHOOL YEAR



Since the placebo group did not receive any Fe treatment (it was simply carried over time with a sugar tablet intervention) the set of values obtained for this group would represent those for the normal population. This group thus functioned as a control group for the experimental (Fe treated) group. A comparison between the two groups would thus elicit the impact of Fe supplementation on the study population.

Between group comparison

Iron supplementation at a dose of 60 mg elemental Fe/day for 60 days at a stretch, twice in the school year facilitated in filling up the Fe stores for these subjects.

The frequency distribution of Hb values in the 102 subjects in the two groups (Table 12 and Fig. 11) revealed that nearly 67 percent of the Fe treated subjects had Hb values greater than 12 g/dl as against 9 percent in the placebo group.

The independent 't' test was employed to compare the measures of iron status in the two groups. As evident from Table 13 and Fig. 12, the SI and TS values were significantly higher ($p < 0.001$) and TIBC values were significantly ($p < 0.001$) lower in the Fe treated versus the placebo group. The values for SI were 87.93 and 59.18 mcg/dl, for TIBC were 388.03 and 435.33 mcg/dl and for TS were 23.36 and 14.48% for the Fe treated and placebo groups respectively.

When iron stores have been exhausted, the SI and TS values decline. Of the various iron transport measurements, a TS below 16% is considered the best single criterion of impairment of Fe supply to the developing red cell or iron deficiency erythropoiesis (Bainton and Finch, 1964). A corresponding value in children between 6 months to adolescence is 7 to 10% (Koerper and Dallman, 1977).

In the present study the mean TS of the placebo group was 14% as against 23% in the experimental group at final evaluation. Also, 16% of the placebo group subjects and 3% of the experiementals had TS below 10%.

On analysing the same data with age as a variable, no difference was observed between the younger (age $\angle$ 11 years) and the older (age $\geqslant$ 11 years) subjects in either groups. The values for SI, TIBC and TS for the younger and older Fe treated groups were 89.75 Vs 82.48 mcg/dl, 387.09 Vs 390.84 mcg/dl and 23.51 Vs 22.93 percent respectively. Corresponding values for the placebo group were 57.48 Vs 65.10 mcg/dl, 437.96 Vs 426.13 mcg/dl and 13.92 Vs 16.42 percent.

To sum up, the results for Objective I (i.e. iron status of the study population), revealed that :

(1) Prevalence of anemia was near universal (90%) by the WHO cut off point of 12 g/dl at baseline; no difference in prevalence figures between younger (age $<$ 11 yrs) and older (age $\geq$ 11 yrs.) subjects at baseline was observed.

(2) Anemia was mainly due to Fe deficiency, supported by the RCM examination and by nearly 90% subjects responding to Fe supplementation.

(3) On Fe supplementation prevalence of anemia dropped to only 30% (Hb $<$ 12 g/dl).

(4) On withdrawal of Fe supplementation the Hb levels dropped significantly.

(5) Iron Status, measured by SI, TIBC and TS values, was significantly better in the Fe treated than the placebo group indicating that Fe supplementation at a dose of 60 mg elemental Fe per day for 60 days, twice in a school year, helped in filling up of iron stores of these subjects.

DISCUSSION

Amongst the earliest studies Natvig et al (1966 and 1967) reported a prevalence of 9 to 31% in 10 to 13 year old school children from different areas of Norway; prevalence of anemia was reportedly greater in girls than in boys of the same age group.

Results on the prevalence of anemia in the present study were in conformity with those of the previous studies conducted all over India (Indirabai and Ratna Mallika, 1976; Gupta and Saxena, 1977; Tripathi et al, 1982) and on Baroda school children (Kanani and Gopaldas, 1983; Gopaldas et al, 1983).

Lack of folic acid and vitamin B_{12} deficiency in Indian school children has been reported by Saraya (1983) and Rajalakshmi (1975). Gopaldas and Kale (1985) in a study on underprivileged school boys (8-15 years) reported the absence of folic acid deficiency in this group, on the basis of examination of the red cell picture. A similar observation was made in the present study, indicating anemia was primarily due to iron deficiency as indicated by a predominant microcytic hypochromic red cell picture and also the results of the supplementation trial support the fact that anemia was primarily of the iron deficiency type.

Although, it seems reasonable to base the definition of iron deficiency on Hb concentration, the distribution of Hb concentration of normal individuals and those of persons whose Hb concentration are restricted by lack of iron overlap considerably (Garby et al, 1969). Thus many individuals who are potentially iron responsive may be identified as normal or individuals whose Hb values are normally low may be incorrectly labelled as anemic. Therefore, in the recent past numerous studies have based prevalence figures on response to hematinic supplementation (Singla et al, 1980; Margolis et al, 1981).

The prevalence of anemia based on dose response was overwhelmingly high in the present study. This substantiated the high prevalence figures for nutritional anemia in the study population whether assessed by the WHO or Indian cut-off points. It also pointed to the fact that the anemia was predominantly due to Fe deficiency.

Results of the iron status parameters (SI, TIBC and TS) indicated the beneficial effect of Fe therapy on the study population. However, a small proportion of the subjects at the end of the 2nd intervention had a TS value below the normal. The need for continued iron therapy year after year to these children was indicated by a drop in Hb values to baseline values after 4 months of withdrawal of therapy.

Thus, in order to maintain a normal iron status it would be necessary to continue therapy to these children as long as they attend school. Most of the study subjects come from a socio-economic segment where marriage and motherhood would normally follow early in their lives. Consequently, the absence of regular prophylactic Fe supplementation at the level indicated in the present study for as many years as these girls were in school, may result in these girls entering motherhood with poor Fe stores with the distinct possibility of problems of pregnancy to themselves and a poor birth out come to their offspring.

II. Impact of Fe supplementation on selected parameters of Cognitive Function (CF), namely, concentration, memory, discrimination and visual motor coordination.

1. Impact of supplementation on CF test scores of the total study population

The four tests used to study Cognitive Function in relation to Fe supplementation were Clerical Task, Digit Span, Visual Memory and Mazes. The specific areas of cognition tested by these were concentration, perception, memory, discrimination and visual motor coordination.

The tests were conducted on 83 pairs of subjects matched for initial age, Hb, individual and total CF test scores. However, by the end of the study, data on only 65 pairs could be retained for analysis as complete data was available for them.

The CF test scores of the Fe treated group at Baseline, Mid, Final and Post-final evaluations are set out in Table 14 and the corresponding values for the placebo group are indicated in Table 15.

1. Within group comparison

The paired 't' test was used to compare the CF test scores of either groups at Baseline, Mid, Final and Post-final evaluations.

Comparisons made were similar to those for changes in the mean Hb levels.

Table 14. Impact of iron supplementation (60 mg/day for 60 days) twice in a school year on Cognitive Function test scores in underprivileged school girls, 8 - 15 yrs of age.

	Clerical Task	Digit Span	Visual Memory	Mazes	Total Score
Baseline (B)	4.00 $\pm$0.16	3.88 $\pm$0.14	7.89 $\pm$0.19	4.36 $\pm$0.22	20.11 $\pm$0.54
Mid (M)	4.65 $\pm$0.18	4.12 $\pm$0.12	8.08 $\pm$0.14	5.72 $\pm$0.21	22.60 $\pm$0.41
Final (F)	5.83 $\pm$0.20	4.75 $\pm$0.13	8.43 $\pm$0.11	7.54 $\pm$0.20	26.54 $\pm$0.44
Post-final (PF)	5.88 $\pm$0.20	4.54 $\pm$0.14	8.34 $\pm$0.11	6.45 $\pm$0.15	25.22 $\pm$0.39
B Vs M	4.88***	1.96^{NS}	1.04^{NS}	6.45***	7.51***
B Vs F	6.74***	5.38***	2.43*	13.18***	12.08***
B Vs PF	8.13***	4.80***	2.04*	9.54***	10.84***
M Vs F	4.92***	4.79***	2.37*	7.66***	10.42***
M Vs PF	6.33***	3.56**	1.48^{NS}	3.51**	7.57***
F Vs PF	0.42^{NS}	-1.29^{NS}	-1.19^{NS}	-5.92***	-3.60***

NS - Non-significant difference between the means of the two groups compared
* - Difference between the means of the two groups significant at $p < 0.05$
** - Difference between the means of the two groups significant at $p < 0.01$
*** - Difference between the means of the two groups significant at $p < 0.001$

Table 15. Impact of placebo treatment on the Cognitive Function test scores over one year in underprivileged school girls, 8-15 years of age.

	Clerical Task	Digit Span	Visual Memory	Mazes	Total Score
Baseline (B)	4.11 ±0.12	4.04 ±0.13	7.77 ±0.15	4.71 ±0.21	20.55 ±0.46
Mid (M)	4.69 ±0.15	4.22 ±0.13	8.15 ±0.14	5.56 ±0.21	22.71 ±0.45
Final (F)	4.93 ±0.13	4.33 ±0.12	8.3 ±0.13	6.20 ±0.17	23.78 ±0.37
Post-final (PF)	5.46 ±0.15	4.49 ±0.13	8.41 ±0.11	5.98 ±0.17	24.36 ±0.36
B Vs M	4.65***	1.85NS	2.48**	5.28***	5.24***
B Vs F	6.71***	2.97**	2.84**	7.89***	8.13***
B Vs PF	8.75***	5.09***	3.65**	7.40***	8.76***
M Vs F	2.10*	1.29NS	0.78NS	3.21*	3.51**
M Vs PF	4.59***	2.0*	1.46NS	2.18*	4.27***
F Vs PF	3.77***	1.95NS	1.03NS	-1.78NS	1.28NS

Values are mean ± SE.

NS - Difference between the means non-significant
* - Difference between the means significant ($p < 0.05$)
** - Difference between the means significant ($p < 0.01$)
*** - Difference between the means significant ($p < 0.001$)

It is evident from Table 14 that a highly significant ($p < 0.001$) enhancement for the Fe treated group in Clerical Task, Mazes and Total Score were obtained at mid evaluation. These scores further increased significantly at final and post-final evaluations. The enhancement in the Digit Span and Visual Memory tests were delayed, being significant ($p < 0.001$ and $p < 0.05$ respectively) only at final evaluation. A non-significant drop in the Digit Span and Visual Memory test scores were observed from the final values on withdrawal of supplements; yet, these scores were significantly higher than the baseline scores. There was a non-significant increase of 0.05 points in the Clerical Task scores at post-final from the final evaluation. However, a highly significant ($p < 0.001$) drop in the Mazes and Total Score was observed at this stage.

A similar analysis for the placebo group (Table 15) was also made. Results of this set of analysis also indicated significant improvements in Clerical Task, Visual Memory, Mazes and Total score at each evaluation. The Digit Span score increased significantly only at final evaluation. The increase in Total Score from mid to final evaluation was only due to the significant increase in the Clerical Task and Mazes scores. With the withdrawal of placebos, a non-significant increase was observed in the Digit Span, Visual Memory and

Table 16. Comparison of CF test scores at baseline in the Fe treated and placebo groups.

Parameter	Fe treated group N=65	Placebo group N=65	't' values
Hb (g/dl)	10.28 ± 0.14	10.39 ± 0.14	0.5308^{NS}
Clerical task	4.00 ± 0.16	4.11 ± 0.12	0.4836 ^{NS}
Digit span	3.88 ± 0.14	4.04 ± 0.13	0.8083^{NS}
Visual Memory	7.89 ± 0.19	7.77 ± 0.15	0.4906^{NS}
Mazes	4.36 ± 0.22	4.71 ± 0.21	0.3355^{NS}
Total score	20.11 ± 0.54	20.55 ± 0.46	0.6139^{NS}

All values are mean ± SE

NS - Difference between the two groups non-significant

Table 17. Comparison of CF test scores at mid evaluation between the Fe treated and placebo groups.

Parameter	Fe treated group N=65	Placebo group N=65	't' values
Hb (g/dl)	11.61±0.14	10.71±0.12	4.3876***
Clerical task	4.65 ±0.18	4.69±0.15	0.1839^{NS}
Digit span	4.12±0.12	4.22±0.13	0.5530^{NS}
Visual memory	8.09±0,14	8.15±0.14	0.3178^{NS}
Mazes	5.72±0.21	5.56±0.21	0.5557^{NS}
Total score	22.60±0.41	22.71±0.45	0.1762^{NS}

All values are mean ± SE

NS - Difference between the two groups non-significant

*** Difference between the two groups significant at $p < 0.001$.

Table 18. Comparison of CF test scores at final evaluation between the Fe treated and placebo groups.

Parameters	Fe treated group N=65	Placebo group N=65	't' values
Hb (g/dl)	12.33±0.09	10.68±0.11	10.7831***
Clerical task	5.83±0.20	4.93±0.13	3.6648***
Digit span	4.75±0.13	4.33±0.12	2.3673*
Visual memory	8.43±0.11	8.3±0.13	0.7245NS
Mazes	7.54±0.20	6.20±0.17	4.8910***
Total score	26.54±0.44	23.78±0.37	4.7564***

All values are mean ± SE

NS - Difference between the mean non-significant

* - Difference between the means significant (p $\angle$0.05)

*** Difference between the means significant (p $\angle$0.001).

Total scores from the final scores. However, in the Mazes score a non-significant drop was obtained. The only test score that showed a further significant enhancement from the final value was the Clerical Task.

Scores at post-final evaluation for all tests, however, remained significantly higher than those at baseline.

The increments in the scores of the placebo group over the entire study period could be attributed to their familiarisation with the tests on subsequent testing. A similar increment (attributable to familiarisation) could also be expected in the iron treated group. Thus, it became necessary to compare the two groups to establish the extent of familiarisation in the Fe treated group. An increment greater than that observed in the placebo group would give the true benefit of Fe supplementation on CF test scores.

2. Between group comparison

The Fe treated and placebo groups did not differ significantly with respect to any Cognitive Function test scores at baseline (Table 16) nor at mid evaluation (Table 17), although the Hb values had increased significantly at mid evaluation in the Fe treated group.

However, at final evaluation (Table 18), a significantly higher score than the placebo group for Clerical Task, Digit Span, Mazes and Total Score was observed in the Fe treated group. The difference between the Visual Memory test scores for the two treatment groups was non-significant, although, a similar trend was observed.

Table 19. Comparison of CF test scores of post-final evaluation between Fe treated and placebo group

Parameters	Fe treated group N=65	Placebo group N=65	't' values
Hb (g/dl)	10.65±0.12	10.37±0.11	1.6734^{NS}
Clerical Task	5.88±0.20	5.46±0.15	1.5732^{NS}
Digit Span	4.54±0.14	4.49±0.13	0.2740^{NS}
Visual Memory	8.34±0.11	8.41±0.11	-0.4896^{NS}
Mazes	6.45±0.15	5.98±0.17	1.9642*
Total Score	25.22±0.39	24.36±0.36	1.6059^{NS}

All values are mean ± SE

NS - Difference between the means non-significant

* Difference between the means significant ($p < 0.05$).

FIG. 13 CHANGES IN CF TEST SCORES IN THE Fe TREATED Vs PLACEBO GROUP AT 0, 4TH, 8TH. AND 12TH mTH. OF THE STUDY

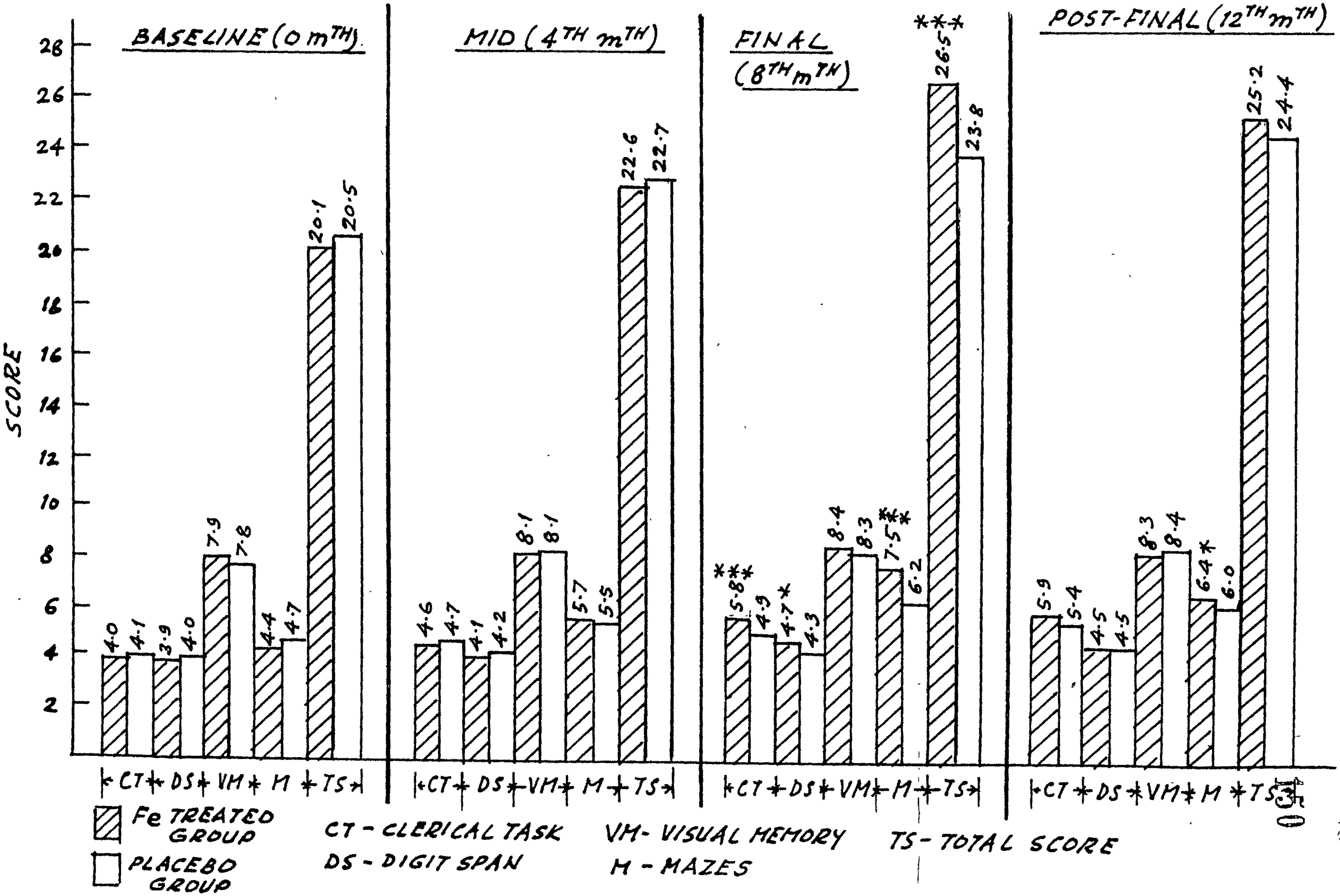


Table 20. Correlation matrix for iron status and selected Cognitive Function test in the Fe treated subjects.

	Clerical Task				Digit Span				Visual Memory				Mazes				Total Score			
	B	M	F	PF	B	M	F	PF	B	M	F	PF	B	M	F	PF	B	M	F	PF
Hb (B)	0.0959		-0.0125		-0.0711		-0.1622		-0.0496		-0.0515		-0.0265		0.0134		-0.1026		0.1622	
Hb (M)		0.076				0.1170				0.0549				0.1243				-0.0847		
Hb (F)			-0.1003				-0.1036				0.0269				0.0132				-0.0917	
Hb (PF)				-0.003				-0.0379				-0.0737				0.0517				-0.0736
SI			-0.0467				0.0092				0.1767				0.1373				0.0757	
TIBC																				
TS			-0.1475				0.0997				-0.1958				-0.257*				-0.1860	

* Correlation coefficient (r) significant at $p < 0.05$.

Hb - Hemoglobin
SI - Serum iron
TIBC - Total iron binding capacity
TS - Transferrin saturation

B - Baseline
M - Mid evaluation
F - Final evaluation
PF - Post-final evaluation

At post-final evaluation (Table 19) the difference between the two treatment groups was non-significant for any of the tests, except for Mazes ($p < 0.05$) which continued to remain high in the Fe treated group.

Results of Tables 14 and 15 indicate that familiarisation with the tests on repeated testing could result in increments in CF test scores. However, from Table 16 to Table 19 and Fig. 13, it is evident that this learning is much greater in the Fe treated group, which unlike the response in Hb values is delayed. It is evident that the improvements are in discrimination, perception and visual motor coordination which were measured by the Clerical Task and Mazes tests. The beneficial effect on visual motor coordination was sustained for atleast 4 months after withdrawal of Fe supplements.

2 Relationship between measures of iron status and CF test scores

In order to study the relationship, if any between iron status and the various CF tests in the present study, the correlation coefficient (r) was determined for each of the parameters.

Results of the correlation coefficient (Table 20) indicated no relationship between Hb status and any of the CF tests; and no relationship between measures of iron status, namely, SI, TIBC

Table 21. Impact of Fe supplementation on anemic (Hb $\leqslant$ 10.50 g/dl) subjects, over one year study period.

n=36	Hb (g/dl)	Clerical Task	Digit Span	Visual Memory	Mazes	Total Score
Baseline (B)	9.48±0.13	3.93±0.22	3.84±0.22	7.80±0.22	4.21±0.27	19.79±0.69
Mid (M)	11.06±0.18	4.52±0.22	4.13±0.19	8.02±0.19	5.71±0.28	21.84±0.70
Final (F)	11.95±0.13	5.86±0.24	4.72±0.17	8.36±0.13	7.40±0.26	25.79±0.80
Post-final (PF)	10.90±0.144	5.55±0.24	4.38±0.20	8.33±0.12	6.33±0.21	24.62±0.50
B Vs M	10.38***	3.83***	1.74^{NS}	1.07^{NS}	5.18***	5.90***
B Vs F	16.25***	7.55***	4.15***	2.33*	9.60***	8.81***
B Vs PF	5.50***	6.52***	3.32**	2.32*	6.71***	7.89***
M Vs F	6.34***	5.91***	4.14***	1.74^{NS}	5.14***	7.56***
M Vs PF	-6.11***	5.26***	1.76^{NS}	1.47^{NS}	2.14*	5.24***
F Vs PF	-12.66***	-2.38*	-1.93^{NS}	-0.40^{NS}	-4.37***	-3.98***

All values are mean ± SE

NS - Difference between the means non-significant

* Difference between the means significant ($p < 0.05$)

** Difference between the means significant ($p < 0.01$)

*** Difference between the means significant ($p < 0.001$)

and TS and any of the CF test scores was observed. The only exception was the Mazes score. The results indicated an inverse relationship ($r = -0.257$, $p < 0.05$) between the Mazes score and TIBC values.

3. Impact of Fe supplementation on anemic and non-anemic subjects in CF test scores

In the present study an attempt was made to examine the CF test scores of the anemic and the non-anemic subjects over the entire study period. Also, a comparison between the scores of the two groups were made at baseline, mid, final and post-final evaluations.

For this purpose, subjects with Hb $\leq$ 10.5 g/dl at baseline were classified as anemics and those with Hb $\geq$ 11.5 g/dl at baseline as non-anemics. The subjects with intermediate Hb levels were deleted from this analysis.

The statistical tests used were :

(1) the paired 't' test for within group comparisons as for I.2, and

(2) the independent 't' test for between group comparisons as for I.2.

The Fe supplemented anemics improved significantly (Table 21) in their Hb values, Clerical Task, Mazes and Total Score at mid and

Table 22. Impact of iron supplementation on the non-anemic (Hb $\geq$ 11.5 g/dl) subjects, over one year study period.

n=10	Hb (g/dl)	Clerical Task	Digit Span	Visual Memory	Mazes	Total Score
Baseline (B)	11.96±0.14	4.36±0.43	3.97±0.33	7.8±0.61	4.81±0.51	21.14±1.11
Mid (M)	12.85±0.24	5.49±0.64	4.35±0.19	8.4±0.29	5.62±0.46	23.56±1.02
Final (F)	12.96±0.22	6.33±0.79	4.69±0.27	8.5±0.32	7.66±0.53	26.84±1.47
Post-final(PF)	11.66±0.22	6.67±0.63	4.71±0.23	8.2±0.37	6.43±0.29	26.00±0.85
B Vs M	3.04*	2.58*	1.19^{NS}	0.13^{NS}	1.68^{NS}	3.33**
B Vs F	3.36**	2.91*	1.62^{NS}	0.34^{NS}	6.06***	4.06**
B Vs PF	-1.44^{NS}	5.16***	1.91^{NS}	0.23^{NS}	4.22**	4.62***
M Vs F	0.87^{NS}	1.70^{NS}	1.41^{NS}	0.45^{NS}	4.16**	3.70**
M Vs PF	-3.90**	4.42**	2.71*	0.25^{NS}	1.68^{NS}	3.83**
F Vs PF	-3.83**	0.65	0.06	-0.56^{NS}	-2.49*	-0.88^{NS}

All values are mean ± SE

NS - Difference between the means non-significant
* Difference between the means significant ($p < 0.05$)
** Difference between the means significant ($p < 0.01$)
*** Difference between the means significant ($p < 0.001$)

Table 23. Changes in CF test scores among anemic (Hb $\leq$ 10.5 g/dl) subjects in the placebo group.

n=45	Hb (g/dl)	Clerical Task	Digit Span	Visual Memory	Mazes	Total Score
Baseline (B)	9.60±0.13	3.92±0.19	4.02±0.18	7.52±0.27	4.18±0.30	20.09±0.59
Mid (M)	10.03±0.12	4.56±0.22	4.18±0.20	8.28±0.19	5.49±0.28	22.68±0.67
Final (F)	10.06±0.11	4.69±0.19	4.44±0.18	8.28±0.22	5.99±0.23	23.34±0.58
Post-final (PF)	9.81±0.09	5.33±0.24	4.59±0.17	8.31±0.16	5.96±0.24	24.13±0.55
B Vs M	3.14**	3.51**	1.15^{NS}	2.11**	4.25***	4.28***
B Vs F	3.42**	4.32***	2.25*	1.57^{NS}	5.97***	5.43***
B Vs PF	1.88^{NS}	6.73***	3.69***	1.90^{NS}	6.19***	5.66***
M Vs F	0.49^{NS}	1.10^{NS}	1.33^{NS}	0.0^{NS}	2.01^{NS}	1.88^{NS}
M Vs PF	-2.40*	3.76***	2.61*	0.12^{NS}	2.03*	2.04*
F Vs PF	-2.62*	3.83***	1.37^{NS}	0.16^{NS}	-0.26^{NS}	0.64^{NS}

All values are means ± SE

NS - Difference between means non-significant
* Difference between means significant ($p < 0.05$)
** Difference between means significant ($p < 0.01$)
*** Difference between means significant ($p < 0.001$)

Table 24. Changes in CF test scores among non-anemic (Hb $\geq$ 11.5 g/dl) subjects, in the placebo group.

n=10	Hb (g/dl)	Clerical Task	Digit Span	Visual Memory	Mazes	Total Score
Baseline (B)	12.33±0.22	4.74±0.29	4.41±0.58	7.62±0.42	4.78±0.42	21.55±1.13
Mid (M)	12.27±0.20	4.98±0.18	4.63±0.16	8.37±0.24	5.23±0.65	23.23±0.87
Final (F)	12.11±0.20	5.61±0.12	4.78±0.16	8.37±0.30	6.19±0.40	24.95±0.62
Post-final (PF)	11.85±0.26	6.14±0.19	4.92±0.23	8.5± 0.25	5.77±0.48	25.37±0.62
B Vs M	-0.28	0.86^{NS}	2.05^{NS}	1.00^{NS}	1.20^{NS}	2.72*
B Vs F	-1.21	3.04*	2.37*	1.27^{NS}	4.56**	4.04**
B Vs PF	-6.37***	3.11*	2.47*	1.31^{NS}	3.33**	5.23***
M Vs F	-1.18	2.52*	1.00^{NS}	0.00^{NS}	1.68^{NS}	2.12^{NS}
M Vs PF	-2.47*	3.53**	1.15^{NS}	0.55^{NS}	0.91^{NS}	3.78**
F Vs PF	-1.47	2.18^{NS}	0.75^{NS}	0.42^{NS}	-1.44^{NS}	1.15^{NS}

All values are mean ± SE

NS - Difference between means non-significant
* Difference between means significant ($p < 0.05$)
** Difference between means significant ($p < 0.01$)
*** Difference between means significant ($p < 0.001$)

further increments were observed at final evaluation. Although, these scores dropped significantly at post-final from the final scores, they were higher than those at baseline. The increase in scores for Digit span and Visual Memory were significant only at final evaluation and the drop in these scores at post-final was non-significant from final scores, the scores remained higher than those at baseline.

The picture for the Fe treated non-anemics differed slightly from that of the anemics (Table 22).

In this group, at mid evaluation, a significant improvement was observed only in the Clerical Task and Total Score. At final evaluation, the benefit of Fe supplementation was obtained in Mazes score also. These scores remained significantly higher at post-final than the baseline scores, although, a non-significant drop in Hb level was observed. The scores for Clerical Task and Digit Span had improved slightly at post-final from those at final evaluation. The scores for Visual Memory, Mazes and Total Score dropped during the same period, significant only for Mazes ($p < 0.05$) score.

Similar analysis for the placebo treated anemics (Table 23) and non-anemic (Table 24) indicated -

(1) Significant improvement at mid evaluation for Clerical Task, Visual Memory, Mazes and Total Score.

(2) significant improvement at final evaluation for Clerical Task, Digit Span, Mazes and Total Score. These scores remained significantly higher than the baseline scores at post-final evaluation.

(3) A significant increase from final to post-final scores was observed only for Clerical Task. Minor increments in scores were also obtained for Digit Span, Visual Memory and Total Score.

(4) A non-significant drop in Mazes was observed at post-final evaluation.

Table 24 presents the changes in Hb and CF test scores in the placebo treated non-anemic subjects. Results indicated that in this group significant improvement was observed at final evaluation for Clerical Task, Digit Span, Mazes and Total Score. The scores at post-final remained significantly higher than those at baseline evaluation. With the exception of Mazes, where a minor drop in score was observed, the scores for all other tests increased further from those at final to the post-final evaluation scores.

It appeared from Tables 21 and 22 and Tables 23 and 24, that when the within group comparisons were made, the anemics benefitted more than the non-anemics for both the treatment groups.

Table 25. Comparison of anemic versus non-anemic subjects in the iron treated and placebo groups at baseline.

Group	Category	Hb (g/dl)	Clerical Task	Digit Span	Visual Memory	Mazes	Total Score
Fe treated Group	Anemic Hb $\leq$ 10.5 g/dl (36)	9.48 $\pm$0.13	3.93 $\pm$0.22	3.84 $\pm$0.22	7.80 $\pm$0.22	4.21 $\pm$0.27	19.79 $\pm$0.69
	Non-anemic Hb $\geq$ 11.5 g/dl (10)	11.96 $\pm$0.14	4.36 $\pm$0.43	3.37 $\pm$0.33	7.80 $\pm$0.61	4.81 $\pm$0.51	21.14 $\pm$1.11
	't' values	12.72***	0.88^{NS}	0.33^{NS}	0	1.02^{NS}	1.02^{NS}
Placebo Group	Anemic Hb $\leq$ 10.5 g/dl (45)	9.60 $\pm$0.13	3.92 $\pm$0.19	4.02 $\pm$0.18	7.52 $\pm$0.27	4.18 $\pm$0.30	20.09 $\pm$0.59
	Non-anemic Hb $\geq$ 11.5 g/dl (10)	12.33 $\pm$0.22	4.74 $\pm$0.29	4.41 $\pm$0.23	7.62 $\pm$0.58	4.78 $\pm$0.42	21.55 $\pm$1.13
	't' values	10.57***	2.33*	1.30^{NS}	0.15^{NS}	1.15^{NS}	1.14^{NS}

All values are mean $\pm$ SE

NS - Difference between means non-significant
* Difference between means significant ($p < 0.05$)
*** Difference between means significant ($p < 0.001$)

Table 26. Comparison of anemic versus non-anemic subjects in the iron treated and placebo groups at mid evaluation.

Group	Category	Hb (g/dl)	Clerical Task	Digit Span	Visual Memory	Mazes	Total Scores
Fe treated Group	Anemic Hb $\leq$ 10.5 g/dl (36)	11.06 $\pm$0.18	4.52 $\pm$0.22	4.13 $\pm$0.15	8.02 $\pm$0.19	5.71 $\pm$0.28	21.84 $\pm$0.70
	Non-anemic Hb $\geq$ 11.5 g/dl (10)	12.85 $\pm$0.24	5.49 $\pm$0.64	4.35 $\pm$0.19	8.4 $\pm$0.29	5.62 $\pm$0.46	23.56 $\pm$1.02
	't' values	5.984***	1.425^{NS}	0.9128^{NS}	1.0764^{NS}	0.3167^{NS}	1.394^{NS}
Placebo Group	Anemic Hb $\leq$ 10.5 g/dl (45)	10.03 $\pm$0.12	4.56 $\pm$0.22	4.18 $\pm$0.20	8.28 $\pm$0.22	5.99 $\pm$0.23	23.34 $\pm$0.58
	Non-anemic Hb $\geq$ 11.5 g/dl (10)	12.27 $\pm$0.20	4.98 $\pm$0.18	4.63 $\pm$0.16	8.37 $\pm$0.24	5.23 $\pm$0.65	23.23 $\pm$0.87
	't' values	9.5291***	1.4768^{NS}	1.7465^{NS}	0.2734^{NS}	0.3647^{NS}	0.5023^{NS}

All values are mean $\pm$ SE

NS - Difference between means non-significant

*** Difference between means significant ($p < 0.001$)

Table 27. Comparison of anemic versus non-anemic subjects in the iron treated and placebo groups at final evaluation

Group	Category	Hb (g/dl)	Clerical Task	Digit Span	Visual Memory	Mazes	Total Score
Fe treated Group	Anemic Hb $\leq$ 10.5 g/dl (36)	11.95 $\pm$0.13	5.86 $\pm$0.24	4.72 $\pm$0.17	8.36 $\pm$0.13	7.40 $\pm$0.26	25.79 $\pm$0.80
	Non-anemic Hb $\geq$ 11.5 g/dl (10)	12.96 $\pm$0.22	6.33 $\pm$0.79	4.69 $\pm$0.27	8.5 $\pm$0.32	7.66 $\pm$0.53	26.84 $\pm$1.47
	't' values	3.764***	0.5749^{NS}	0.093^{NS}	0.3950^{NS}	0.4383^{NS}	0.6255
Placebo Group	Anemic Hb $\leq$ 10.5 g/dl (45)	10.06 $\pm$0.11	4.69 $\pm$0.19	4.44 $\pm$0.18	8.28 $\pm$0.22	5.99 $\pm$0.23	23.34 $\pm$0.58
	Non-anemic Hb $\geq$ 11.5 g/dl (10)	12.11 $\pm$0.20	5.61 $\pm$0.12	4.78 $\pm$0.16	8.37 $\pm$0.30	6.19 $\pm$0.40	24.95 $\pm$0.62
	't' values	8.9973***	4.0086***	1.405^{NS}	0.2272^{NS}	$0,5011^{NS}$	1.8875^{NS}

All values are mean $\pm$ SE

NS - Difference between means non-significant

*** Difference between means significant ($p \angle 0.001$)

Table 28. Comparison of anemic versus non-anemic subjects in the iron treated and placebo groups at post-final evaluation.

Group	Category	Hb (g/dl)	Clerical Task	Digit Span	Visual Memory	Mazes	Total Score
Fe treated Group	Anemic Hb $\leq$ 10.5 g/dl (36)	10.09 $\pm$0.14	5.55 $\pm$0.24	4.38 $\pm$0.20	8.33 $\pm$0.12	6.33 $\pm$0.21	24.62 $\pm$0.50
	Non-anemic Hb $\geq$ 11.5 g/dl (10)	11.66 $\pm$0.22	6.67 $\pm$0.63	4.71 $\pm$0.23	8.2 $\pm$0.37	6.43 $\pm$0.29	26.00 $\pm$0.85
	't' values	5.9832***	1.658^{NS}	1.049^{NS}	0.3419^{NS}	0.2610^{NS}	1.3938^{NS}
Placebo Group	Anemic Hb $\leq$ 10.5 g/dl (45)	9.81 $\pm$0.09	5.33 $\pm$0.24	4.59 $\pm$0.17	8.31 $\pm$0.16	5.96 $\pm$0.24	24.13 $\pm$0.55
	Non-anemic Hb $\geq$ 11.5 g/dl (10)	11.85 $\pm$0.26	6.14 $\pm$0.19	4.92 $\pm$0.23	8.5 $\pm$0.25	5.77 $\pm$0.48	25.37 $\pm$0.62
	't' values	7.1963***	2.645*	1.1168^{NS}	0.6122^{NS}	0.3498^{NS}	1.4935^{NS}

All values are mean $\pm$ SE

NS - Difference between means non-significant

* Difference between means significant ($p < 0.05$)

*** Difference between means significant ($p < 0.001$)

Table 29(a). Comparison of CF test scores of the anemic subjects in the Fe treated versus placebo group at final evaluation.

Groups	Clerical Task	Digit Span	Visual Memory	Mazes	Total Score
Fe treated anemics	5.86±0.24	4.72±0.17	8.36±0.13	7.40±0.26	25.79±0.80
Placebo group anemics	4.69±0.19	4.44±0.18	8.28±0.22	5.99±0.23	23.34±0.58
't' values	3.822***	1.1313^{NS}	0.4305^{NS}	4.0622***	2.4795*

All values are mean ± SE

Anemics - Subjects with Hb $\leqslant$ 10.5 g/dl at baseline.

NS - Difference between means non-siginficant

* Difference between means significant ($p \angle 0.05$)

*** Difference between means significant ($p \angle 0.001$)

Table 29 (b). Comparison of CF test scores of the non-anemic subjects in the Fe treated versus placebo group at final evaluation.

Groups	Clerical Task	Digit span	Visual Memory	Mazes	Total Scores
Fe treated non-anemics	6.33 ± 0.79	4.69 ± 0.27	8.5 ± 0.32	7.66 ± 0.53	26.84 ± 1.47
Placebo group non-anemics	5.61 ± 0.12	4.78 ± 0.16	8.37 ± 0.30	6.19 ± 0.40	24.95 ± 0.62
't' values	0.9011^{NS}	0.2868^{NS}	0.2964^{NS}	2.2134*	1.1846^{NS}

All values are mean $\pm$ SE

Non-anemics - Subjects with Hb $\geqslant$ 11.5 g/dl at baseline.

NS - Difference between means non-significant

* Difference between means significant ($p < 0.05$)

In order to verify this it was necessary to compare the anemic versus the non-anemic subjects for each of the treatment groups using the independent 't' test. Results of these comparisons are presented in Tables 25 to 28.

It can be concluded here, that there was no extra benefit to the anemics compared to their non-anemic counterparts for either treatment groups. The scores of the non-anemics were greater than those of the anemics, and this trend remained all through the study period.

At final evaluation the CF test scores of the anemics in the Fe treated group were compared with those of the placebo group. A similar comparison was also made for the non-anemic subjects.

Results (Table 29a and 29b) indicated a significantly higher score for Clerical Task, Mazes and Total score for anemics (Table 29a) and only in Mazes for the non-anemics (Table 29b) in the Fe treated group.

Finally, here it may be concluded that when anemics were compared with the non-anemics in each treatment group, anemics showed no significant benefit in CF test scores over and above that of the non-anemics. However, when the effect of treatment (Fe or placebo) was compared in the anemics at final evaluation significant betterment was observed in the Fe treated group for Clerical Task, Mazes and Total Score. A similar comparison made for the non-anemics indicated a benefit only in the Mazes score.

These results, only indicate a greater benefit of Fe therapy to the anemics but no conclusive result could be obtained.

4. Impact of Fe supplementation on younger and older subjects in CF tests

Most of the studies conducted in the relationship between anemia and Cognitive Function have been either on animals (Mackler et al, 1978; Youdim et al, 1980; Weinberg et al, 1980), or on infants (Pollitt et al, 1978; Oski and Honig, 1978; Lozoff et al, 1982) or on preschoolers (Pollitt et al, 1983; Seshadri et al, 1982).

Webb and Oski (1973) compared the CF test scores of anemic versus non-anemic school children from two different ethnic groups, which was a major methodologic flaw in their study. There has been only one study to our knowledge by Gopaldas et al (1985a) reporting the impact of Fe supplementation in underprivileged school children on CF test scores. The study was conducted on carefully pair matched underprivileged school boys (8-15 years of age) from similar family backgrounds. However, no attempt was made in this study to compare the scores of the younger with older boys.

Table 30. Impact of Fe supplementation on CF test scores in the younger (age $<$ 11 yrs.) subjects over one year study period.

n=43	Hb (g/dl)	Clerical Task	Digit Span	Visual Memory	Mazes	Total Score
Baseline (B)	10.23±0.14	3.59±0.18	4.01±0.19	7.62±0.26	4.00±0.27	19.19±0.70
Mid (M)	11.59±0.14	4.14±0.18	4.20±0.15	8.0 ±0.18	5.52±0.26	21.86±0.51
Final (F)	12.35±0.75	5.47±0.22	4.89±0.14	8.55±0.13	7.44±0.24	26.33±0.51
Post-final (PF)	10.60±0.14	5.48±0.24	4.68±0.18	8.48±0.13	6.29±0.17	24.95±0.47
B Vs M	10.65***	3.91***	1.38^{NS}	1.45^{NS}	5.56***	5.87***
B Vs F	17.59***	5.26***	4.35***	3.17**	11.14***	10.27***
B Vs PF	3.02**	6.56***	4.32***	3.04**	8.51***	10.02***
M Vs F	10.79***	4.17***	4.51***	3.10**	6.29***	9.46***
M Vs PF	-6.93***	5.27***	2.95**	2.46*	2.88**	7.28***
F Vs PF	-13.60***	0.10^{NS}	-0.89^{NS}	-0.81^{NS}	-4.61***	-2.67*

All values are mean ± SE

NS - Difference between means non-significant

* Difference between means significant ($p < 0.05$)

** Difference between means significant ($p < 0.01$)

*** Difference between means significant ($p < 0.001$)

Table 31. Impact of Fe supplementation on CF test scores in the older (age $\geq$ 11 yrs.) subjects over one year study period.

n=22	Hb (g/dl)	Clerical Task	Digit Span	Visual Memory	Mazes	Total Score
Baseline (B)	10.38±0.30	4.82±0.28	3.62±0.20	8.41±0.23	5.06±0.36	21.92±0.68
Mid (M)	11.63±0.30	5.65±0.31	3.95±0.19	8.27±0.20	6.12±0.35	24.05±0.58
Final (F)	12.29±0.19	6.52±0.37	4.48±0.24	8.18±0.19	7.74±0.38	26.94±0.82
Post-final (PF)	10.70±0.24	6.67±0.32	4.27±0.20	8.04±0.17	6.75±0.32	25.74±0.68
B Vs M	6.18***	3.02**	1.38^{NS}	-0.47^{NS}	3.28**	5.16***
B Vs F	7.06***	4.18***	3.10**	-0.87^{NS}	7.20***	6.98***
B Vs PF	2.84**	4.17***	2.31*	-1.40^{NS}	4.57***	4.99***
M Vs F	2.73*	2.56*	2.09*	-0.44^{NS}	4.30***	5.00***
M Vs PF	-5.08***	3.44**	2.32*	-0.89^{NS}	1.97^{NS}	3.03**
F Vs PF	-7.51***	1.02^{NS}	-1.01^{NS}	-0.90^{NS}	-3.83***	-2.91*

All values are mean ± SE

NS - Difference between means non significant.

* Difference between means significant ($p < 0.05$)

** Difference between means significant ($p < 0.01$)

*** Difference between means significant ($p < 0.001$)

Table 32. Changes in the CF test scores of the younger (age $<$ 11 yrs) placebo group subjects over one year study period.

n=48	Clerical Task	Digit Span	Visual Memory	Mazes	Total Score
Baseline (B)	3.99 ± 0.15	3.97 ± 0.15	7.60 ± 0.18	4.41 ± 0.26	20.21 ± 0.59
Mid (M)	4.51 ± 0.16	4.19 ± 0.15	7.81 ± 0.24	5.32 ± 0.24	22.17 ± 0.50
Final (F)	4.71 ± 0.15	4.28 ± 0.14	8.14 ± 0.18	6.02 ± 0.21	23.17 ± 0.45
Post-final (PF)	5.22 ± 0.19	4.38 ± 0.16	8.35 ± 0.14	5.81 ± 0.20	23.77 ± 0.42
B Vs M	3.18**	2.05*	2.19*	4.36***	4.10***
B Vs F	5.25***	2.80**	2.18*	6.52***	6.15***
B Vs PF	6.73***	3.81***	3.38**	5.19***	6.14***
M Vs F	1.30^{NS}	0.82^{NS}	0.51^{NS}	3.07**	2.90**
M Vs PF	2.98**	1.51^{NS}	1.40^{NS}	2.20*	3.10**
F Vs PF	2.50*	0.95^{NS}	1.46^{NS}	-1.41^{NS}	0.73^{nS}

All values are mean $\pm$ SE

NS - Difference between means non-significant

* Difference between means significant ($p < 0.05$)

** Difference between means significant ($p < 0.01$)

*** Difference between means significant ($p < 0.001$)

In the present study, an indepth examination on the CF test scores of the subjects after classifying them into two age categories was made. The age categories were :

(1) Younger girls -- age $<$ 11 years

(2) Older girls -- age $\geq$ 11 years.

The results were as follows :

Highly significant increases in all CF test scores were observed for the Fe treated younger (age $<$ 11 years) subjects at mid (except for Digit Span and Visual Memory), at final and post-final evaluations. A significant drop in the post-final scores from those at final was observed only for Mazes and Total score as illustrated in Table 30.

The results for the older (age $\geq$ 11 years) subjects (Table 31) were similar to those of the younger subjects of the Fe treated group. The only exception was the Visual Memory test which showed no significant change (only a drop) in the scores over the entire study period.

Changes in the CF test scores for the younger and older subjects in the placebo group are indicated in Tables 32 and 33 respectively.

It is evident from Table 32 that significant improvement over time was obtained in the younger placebo group for all CF test scores; scores at post-final remaining significantly higher than those

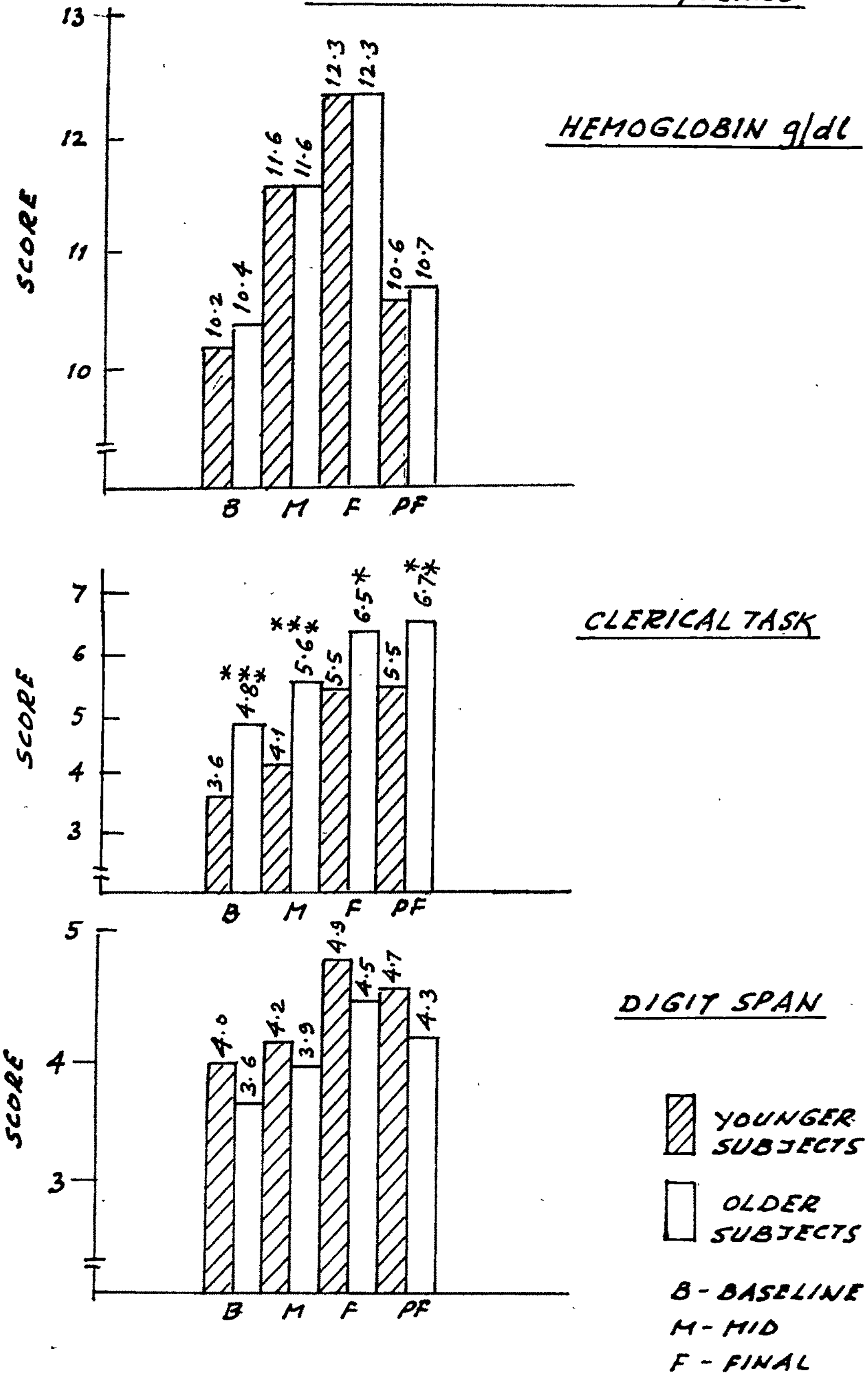
Table 33. Changes in the CF test score of the older (age $\geq$ 11 yrs) placebo group subjects over one year study period.

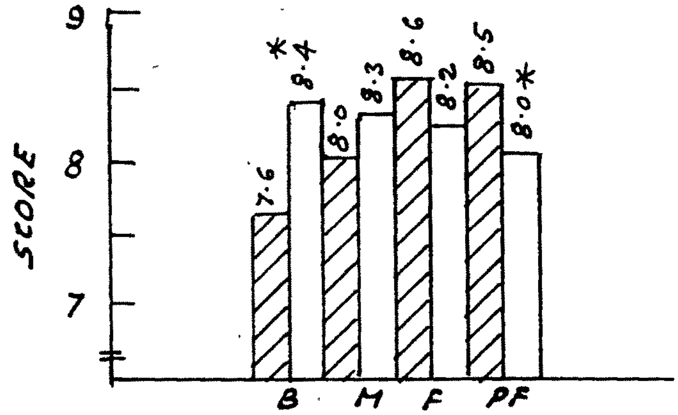
n=22	Clerical Task	Digit Span	Visual Memory	Mazes	Total Score
Baseline (B)	4.35 ± 0.22	4.19 ± 0.25	8.27 ± 0.24	4.59 ± 0.38	21.28 ± 0.67
Mid (M)	5.09 ± 0.29	4.27 ± 0.24	8.45 ± 0.24	6.08 ± 0.36	23.90 ± 0.89
Final (F)	5.42 ± 0.21	4.43 ± 0.23	8.18 ± 0.42	6.59 ± 0.30	25.64 ± 0.59
Post-final (PF)	6.01 ± 0.24	4.71 ± 0.24	8.54 ± 0.14	6.36 ± 0.33	25.64 ± 0.59
B Vs M	2.68*	0.41^{NS}	1.16^{NS}	3.15**	3.23**
B Vs F	4.22***	1.23^{NS}	2.05*	4.46***	5.43***
B Vs PF	5.77***	3.39**	1.44^{NS}	4.33***	7.41***
M Vs F	2.23*	1.19^{NS}	0.75^{NS}	1.27^{NS}	1.94^{NS}
M Vs PF	4.47***	2.58*	0.44^{NS}	0.93^{NS}	3.17**
F Vs PF	3.50**	1.82^{NS}	-0.57^{NS}	-1.08^{NS}	1.50^{NS}

All values are mean $\pm$ SE

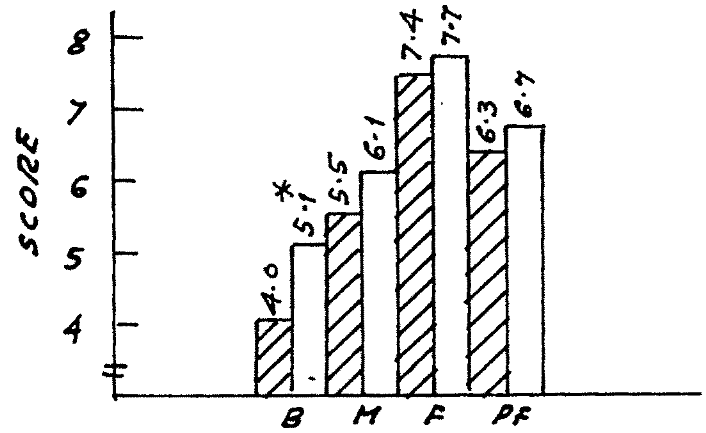
NS - Difference between means non-significant
* Difference between means significant ($p < 0.05$)
** Difference between means significant ($p < 0.01$)
*** Difference between means significant ($p < 0.001$)

FIG. 14 CHANGES IN CF TEST SCORES IN THE YOUNGER (AGE < 11 YRS) Vs OLDER (AGE ≥ 11 YRS.) Fe TREATED SUBJECTS OVER THE ONE YEAR STUDY PERIOD

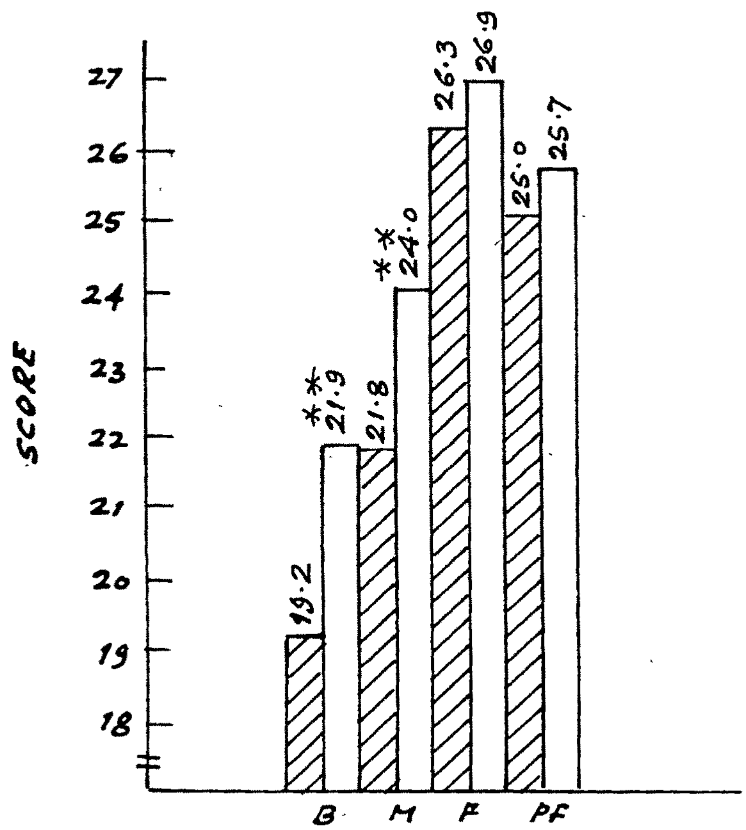




VISUAL MEMORY



MAZES



TOTAL SCORE

* DIFFERENCE BETWEEN MEANS SIGNIFICANT AT $p < 0.05$

** DIFFERENCE BETWEEN MEANS SIGNIFICANT AT $p < 0.01$

*** DIFFERENCE BETWEEN MEANS SIGNIFICANT AT $p < 0.001$

FIG. 15 CHANGES IN CF TEST SCORES IN THE YOUNGER (AGE < 11 YRS) VERSUS OLDER (AGE ≥ 11 YEARS) PLACEBO GROUP SUBJECTS OVER ONE YEAR STUDY PERIOD

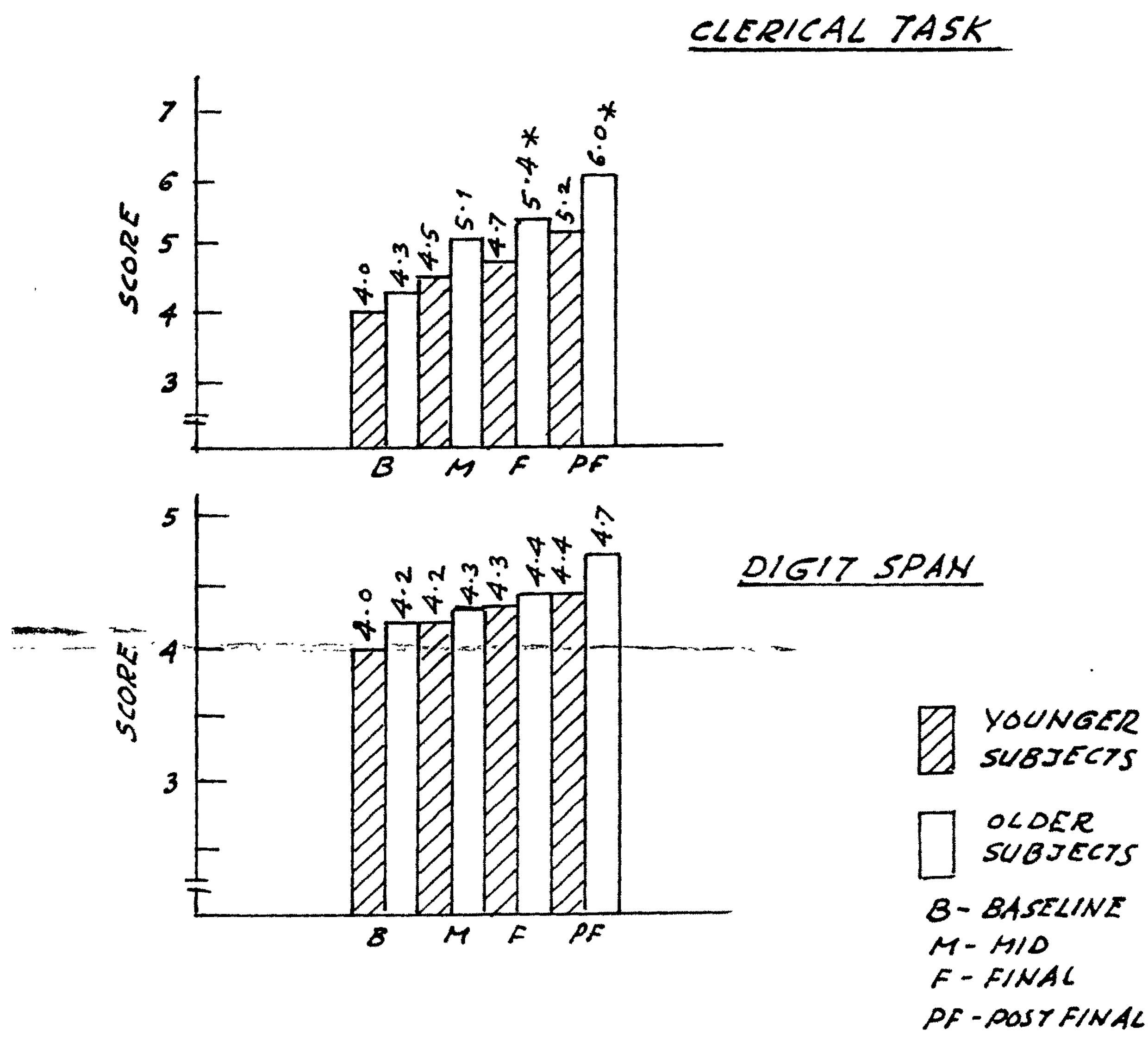
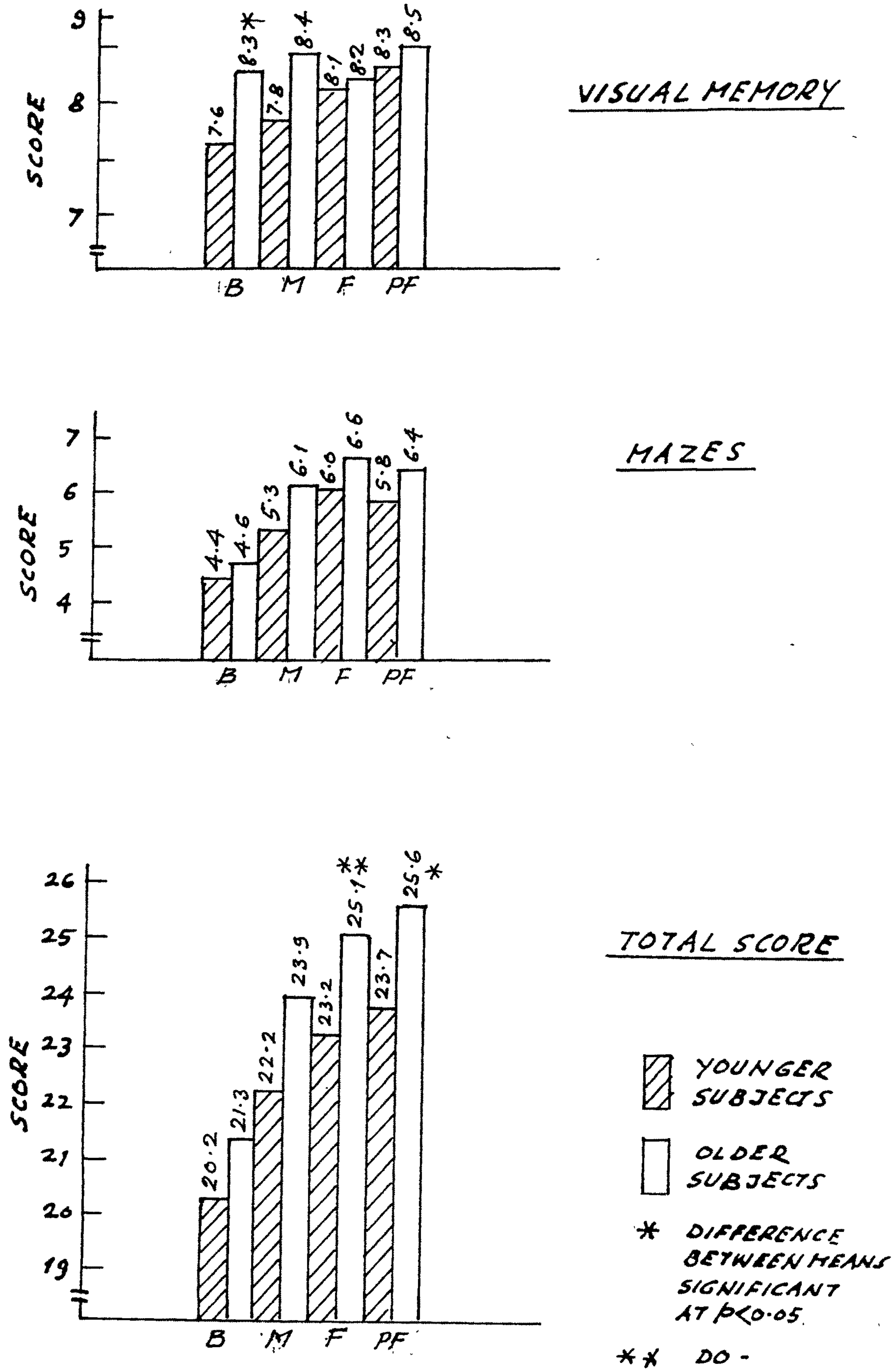


FIG. 15 (CONTD)


VISUAL MEMORY
SCORE
9
8
7
7·6
8·3*
7·8
8·4
8·1
8·2
8·3
8·5
B
M
F
PF
MAZES
SCORE
7
6
5
4
4·4
4·6
5·3
6·1
6·0
6·6
5·8
6·4
B
M
F
PF
TOTAL SCORE
SCORE
26
25
24
23
22
21
20
19
20·2
21·3
22·2
23·9
23·2
25·1**
23·7
25·6*
B
M
F
PF
YOUNGER SUBJECTS
OLDER SUBJECTS
* DIFFERENCE BETWEEN MEANS SIGNIFICANT AT p<0·05
** DO -

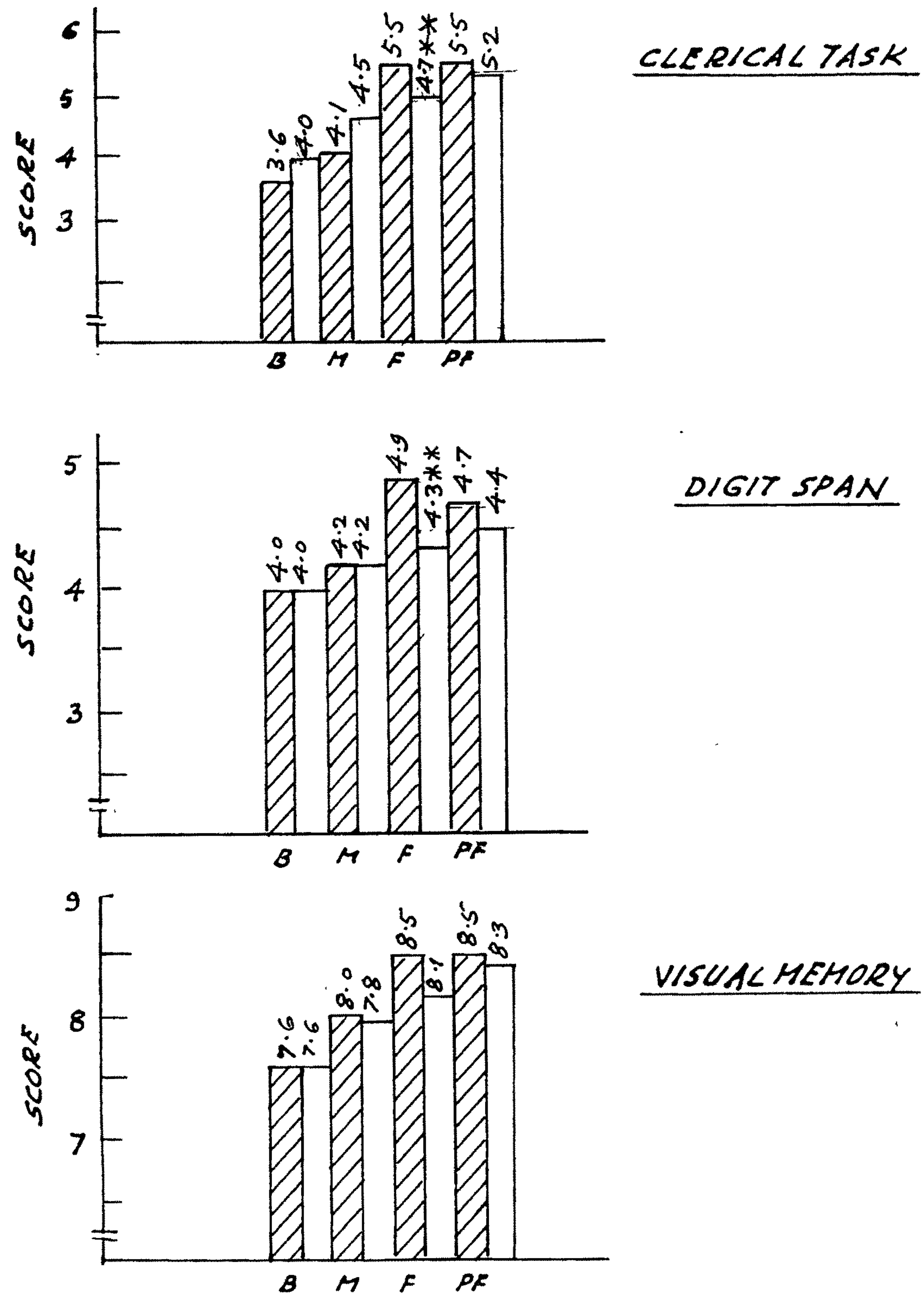
at baseline evaluation. Except for Mazes (where a non-significant drop was observed) all test scores had increased from final values, with a marked increase in Clerical Task ($p < 0.05$) scores at post-final evaluation.

The results of the older placebo group (Table 33) differed slightly from the rest of the groups. Significant improvements were observed at mid for Clerical Task and Total Score; at final for Clerical Task, Visual Memory, Mazes and Total Score. The scores at post-final evaluation were significantly higher than those at baseline for all but Visual Memory test, and for Clerical Task than final scores. A non-significant increase in Digit Span and Total Score; a non-significant decrease in Visual Memory and Mazes score at post-final from final scores was observed.

Figures 14 and 15 illustrate the comparison of the younger versus the older subjects in the Fe treated and placebo groups respectively.

It is apparant that the scores of the younger subjects were lower than those of the older subjects all through, for all tests, for both the treatment groups. The only exception was the Digit Span test score in the Fe treated group. However, the independent 't' test revealed that the younger girls scored significantly less than the older girls only for Clerical Task (all through), Visual Memory (at post-final), Mazes (at baseline) and Total Score (at baseline and mid evaluations) for the Fe treated group (Fig.14).

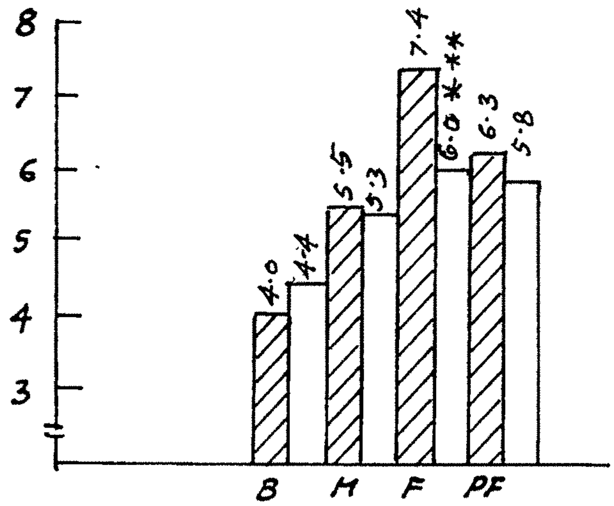
FIG. 16 CF TEST SCORES OF THE Fe TREATED VERSUS THE PLACEBO GROUP, YOUNGER (AGE < 11 YEARS) SUBJECTS, OVER ONE YEAR STUDY PERIOD



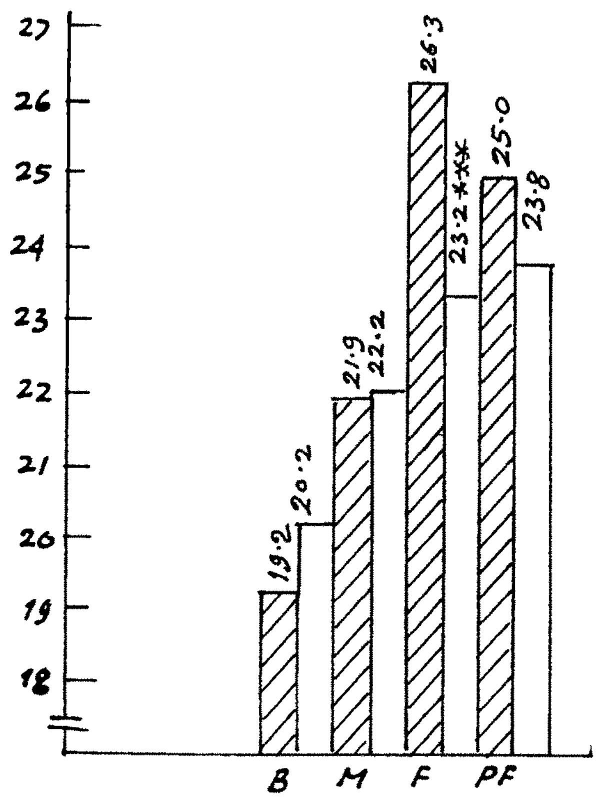
- CONTD -

FIG. 16 (CONTD)

MAZES



TOTAL SCORE



Fe TREATED GROUP

PLACEBO CONTROL GROUP

B - BASELINE

M - MID

F - FINAL

PF - POST-FINAL

** DIFFERENCE BETWEEN MEANS SIGNIFICANT AT $p < 0.01$

*** DIFFERENCE BETWEEN MEANS SIGNIFICANT AT $p < 0.001$

FIG. 17 CF TEST SCORES OF THE Fe TREATED VERSUS THE PLACEBO GROUP, OLDER (AGE ≥ 11 YRS) SUBJECTS OVER ONE YEAR STUDY PERIOD

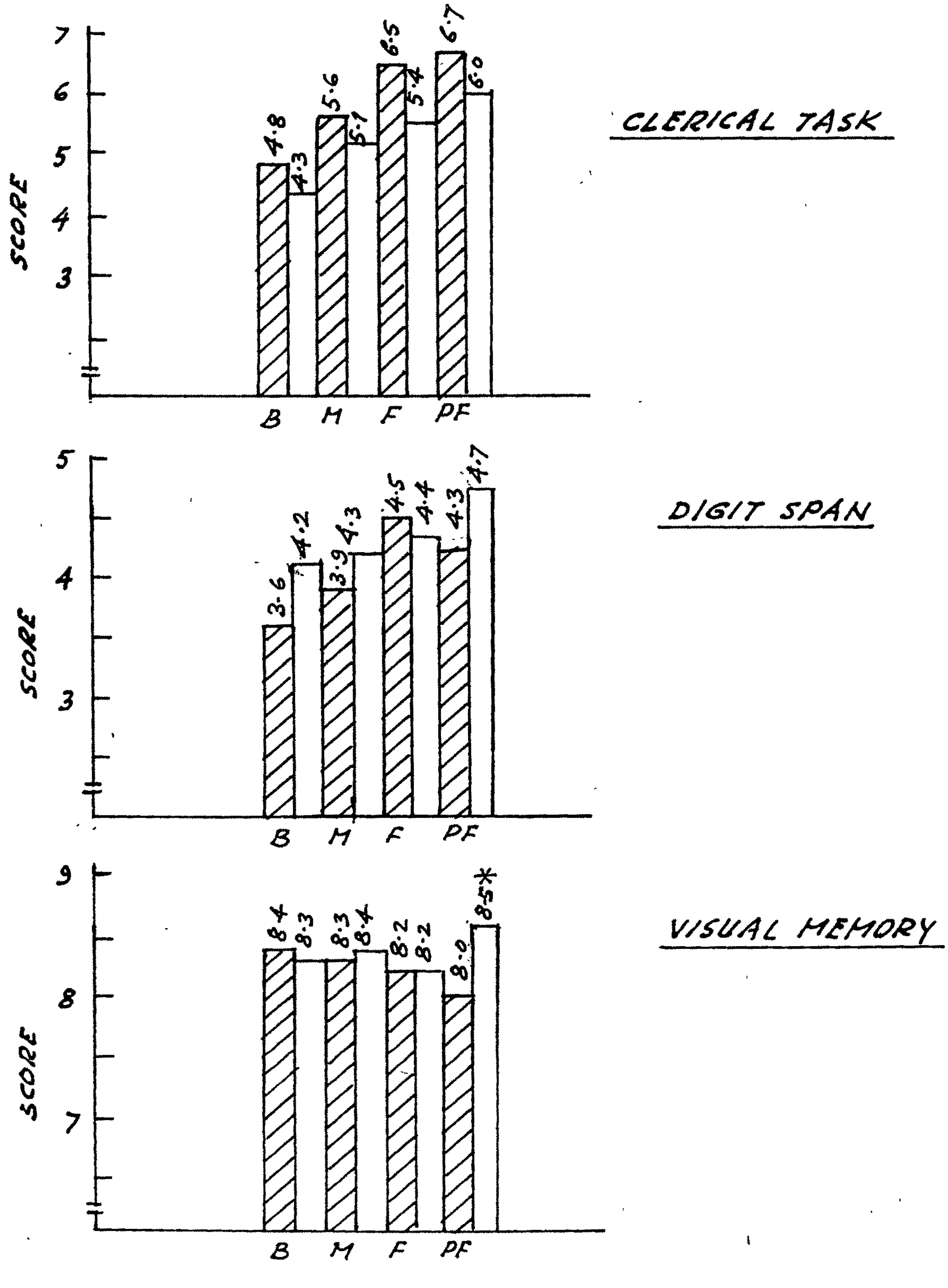
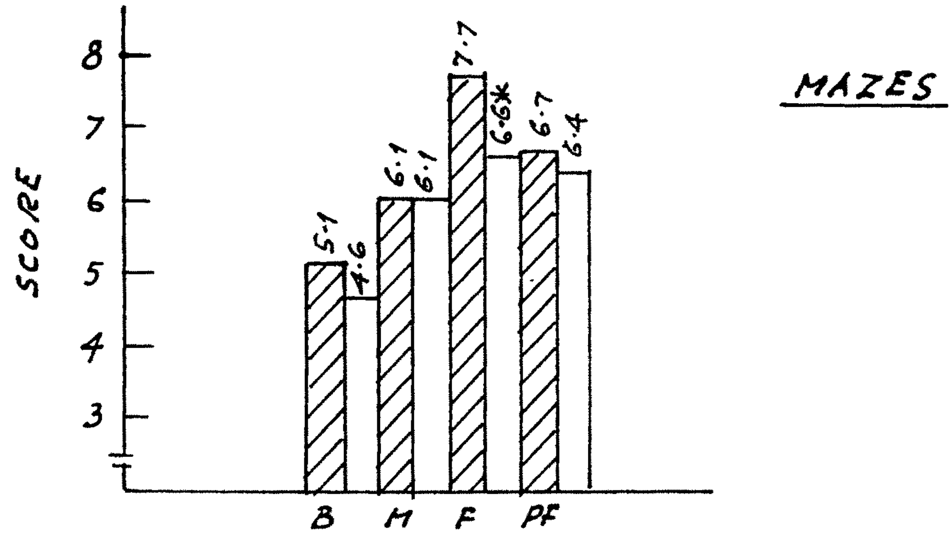


FIG.17 (CONTD)


MAZES
SCORE
8
7
6
5
4
3
5·1
4·6
6·1
6·1
7·7
6·6*
6·7
6·4
B
M
F
PF

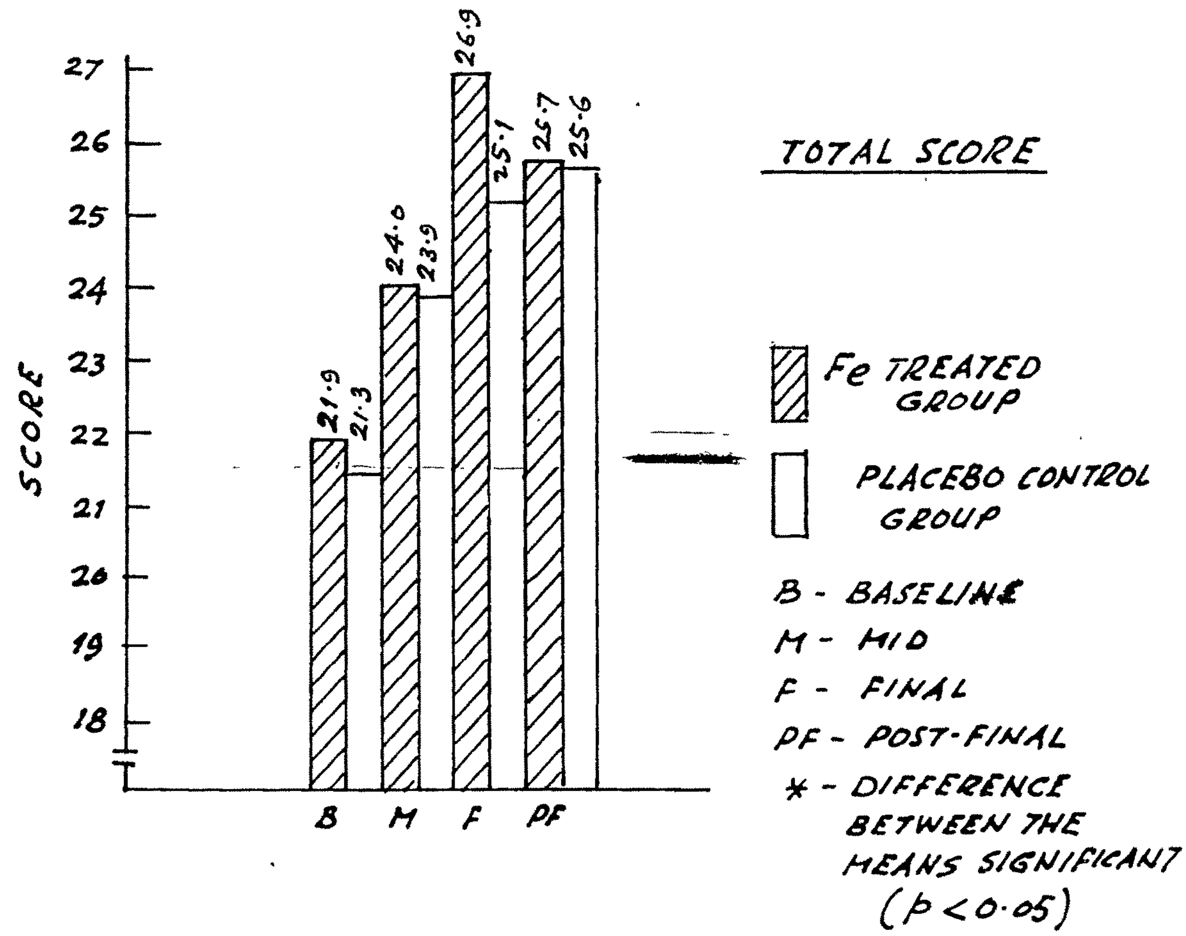

TOTAL SCORE
SCORE
27
26
25
24
23
22
21
20
19
18
21·9
21·3
24·0
23·9
26·9
25·1
25·7
25·6
B
M
F
PF
Fe TREATED GROUP
PLACEBO CONTROL GROUP
B - BASELINE
M - MID
F - FINAL
PF - POST-FINAL
* - DIFFERENCE BETWEEN THE MEANS SIGNIFICANT ($p<0.05$)

Figure 15 indicated the results of the similar comparison for the placebo group. Scores for all CF tests remaining lower in younger than in the older subjects.

From Fig. 14, a trend indicating a beneficial effect of Fe treatment in younger subjects was borne out, depicted by a progressive narrowing in the gap between the scores of the younger and older subjects.

At this stage it was considered important to compare the younger subjects from the two treatment groups for each test and at each point of time. The independent 't' test was employed for the purpose. A similar analysis for the older subjects was also done.

The results substantiated the earlier contention that the benefit of Fe supplementation was greater in the younger age group than in the older age group. As evident from Fig. 16, the scores of the younger subjects at baseline did not differ in the two treatment groups. However, on intervention the scores of the Fe treated group were significantly higher than those of the placebo group at final evaluation for Clerical Task, Digit Span, Mazes and Total Score. Only a similar trend was indicated for Visual Memory test.

Similar analysis for the older group indicated a substantial benefit only for Mazes ($p \angle 0.05$) score; and only a trend for Clerical Task, Digit Span and Total Score was observed (Fig. 17).

To sum up, the results to fulfil Objective II (i.e. Impact of supplementation on Cognitive Function tests) revealed that :

(1) Fe supplementation at the dose level used, brought about an improvement in attention, concentration, discrimination, perception and visual motor coordination as measured by Clerical Task and Mazes test, only at final evaluation.

(2) Beneficial effect of Fe supplementation on perception and visual motor coordination were sustained for atleast four months after withdrawal of Fe supplements.

(3) No difference between the anemics (Hb $\leq$ 10.5 g/dl) and non anemics (Hb $\geq$ 11.5 g/dl) for any of the CF test scores was observed at baseline evaluation. Only a trend for higher scores in non anemics was indicated throughout the study.

(4) Fe supplementation benefitted the younger (age $<$ 11 years) subjects more than the older (age $\geq$ 11 yrs) counterparts.

DISCUSSION

Affective derangements, which may accompany iron deficiency are frequently dramatically remedied within several days after iron therapy has begun (Harris and Kellermeyer, 1970).

Several studies have supported (Oski and Honig, 1978) or refuted (Lozoff et al, 1982; Pollitt et al, 1983) this claim of immediate benefit.

Oski and Honig (1978) reported rapid improvement in Cognitive Function and behavior in a group of iron-deficient infants (9 months to 26 months of age) following iron therapy. A dose sufficient to raise the Hb level to 12 g/dl and also provide extra iron to replenish the body iron stores was administered intramuscularly significant improvement in the Mental Development Index (MDI) of the Bayley scores of Mental Developement Index and Physical Development Index were observed 5-8 days after pre-testing and iron therapy, between the experimental and control groups. Although, the mean scores in the Physical Development Index (PDI) also rose in the experimental group but were not significantly greater than the control group scores. Lozoff et al (1982) however, could not demonstrate any beneficial effects of short term oral iron therapy at a dose of 5 mg Fe/kg body wt/day as ferrous ascorbate, twice daily for one week in the Bayley scales of Infant Development. The study sample was similar to that of Oski and Honig (1978).

The dissonence in the results of the two studies may largely be attributed to the mode of iron supplementation. It is discernable to conclude that, to obtain a beneficial effect of oral iron supplements on Cognitive Function, long term therapy must be advocated.

The results of this present study indicated an oral dose of 60 mg elemental Fe, as $FeSO_4$, per day for 60 consecutive days alone could not ameliorate the CF scores in the experimental group greater than those of the controls. Also, it may be recalled that at mid evaluation the mean Hb levels of the Fe treated group was only 11.6 g/dl and nearly 60% of the subjects had Hb values lower than 12 g/dl. However, on continued oral iron therapy for another 60 days in the second school term, at the same dose level, brought about a significant improvement in test scores for attention, discrimination, memory, perception and visual-motor coordination. The mean Hb value at this stage was 12.33 g/dl and only 25% subjects had not attained a Hb value of 12 g/dl or above. This further substantiates the claim for the need of long term oral iron therapy to obtain an impact on Cognitive Functions.

Two major differences between the present study and those mentioned earlier were :

(1) Period of intervention, which was longer in the present study, and

(2) Differences in the ages of the study population.

It is well known that infancy is the age of rapid growth and most growth (physical and mental) is completed as an individual reaches adolescence.

The major advantage of this long term oral iron therapy was that the effects were sustained for atleast 4 months after withdrawal of treatment in visual-motor coordination (Mazes test).

Most studies documenting the deleterious effects of iron deficiency anemia on cognitive behavior have been conducted either on infants (Oski and Honig, 1978; Lozoff et al, 1982) or on pre-schoolers (Pollitt et al, 1978; Seshadri et al, 1982; Pollitt et al, 1983).

Webb and Oski (1973) reported that anemic, junior high school students (12-14 years old) performed poorly on the achievement tests of the Iowa Test of Basic Skills compared to the non-anemic controls.

The results of the present study did not show any statistical difference between the scores of the anemics (Hb $\leqslant$ 10.5 g/dl) and the non-anemics (Hb $\geqslant$ 11.5 g/dl), although, a trend indicating lower scores for anemics was observed. These results do not conform to those of the studies cited earlier. However, all those studies were conducted on a younger study group, with the exception of the study by Webb and Oski (1973). This study is associated with a major methodologic flaw, that the two groups (anemic and non-anemic) came from different ethnic backgrounds and no attempt was made to match the environment, the role of which in cognitive behavior cannot be ruled out.

Gopaldas et al (1983) reported the impact of Fe supplementation on Cognitive Function, in underprivileged school boys (8-15 years of age). Significant differences in the scores of the anemics and non-anemics were observed.

However, in the present context a greater benefit of Fe treatment was observed in the anemics as compared to that in the non-anemics as indicated in Tables 29a and 29b. It would mean that given the inputs or conditions to improve the iron status, the Fe deficient subjects benefit much more than the non-deficient subjects in their Cognitive Function test scores. Also, it is this group (anemics) that lends a major contribution to the benefit of the total group. These findings are similar to those of Gopaldas et al (1985a) wherein the increase in scores of the anemic boys (8-15 years of age) aid in improving the scores of the total group (anemics, non-anemics and the inbetweens).

As mentioned earlier, age has an important bearing on the development of the brain. The harmful effects of brain insult in early life have well been documented (Cabak and Najdanvic,1965; Champakam et al , 1968; Hertzig et al, 1972; Richardson et al, 1973; Dasen et al, 1977)

Results of a comparison of the impact of Fe dosing on CF test scores in younger (age $<$ 11 years) and older (age $\geq$ 11 yrs) subjects indicated lower scores for younger than older subjects, throughout the study. However, this gap was narrowed on successive testing following iron therapy. This indicated that the benefits of Fe supplementation on CF could largely be attributed to the benefits obtained by the younger group. This is in support of the findings of Elwood and Hughes (1970), who studied 47 placebo and iron treated (150 mg Fe as Fe^{2+} ascorbate daily) women aged 20 years and above. Specific measures of psychomotor functions were tested before and 8 weeks after iron therapy. Results indicated no evidence of a significant difference in the change in performance of subjects given Fe and those given the placebo tablets.

Elwood and Wood (1966) however, had earlier reported that women with severe Fe deficiency anemia responded to oral Fe therapy with improvement in their ability to concentrate and with some reduction in their feeling of fatigue.

Many factors, other than lowered Hb, seem to affect behavior. Results of most earlier studies have therefore been looked at with scepticism, thereby emphasising the need for matching subjects as far as possible.

A plausible biochemical basis for neural dysfunction has been valuable, therefore in validating the results of behavioral studies.

The little that is known of iron in the brain is not widely appreciated, even though earlier studies indicated an interesting distribution and unusual development pattern in man. Of particular relevance to clinical iron deficiency is the fact that brain iron normally increases to adult values during infancy and throughout childhood when iron deficiency is common (Hallgren and Sourander, 1958).

Recently, some research has been conducted to identify the individual compounds that make up the large amount of brain iron, their role in brain function, or their response to nutritional iron deficiency. Symes et al (1969, 1971) suggested that the diminished monoamine oxidase (MAO) activity in iron deficient rats could provide a biochemical basis for behavioral changes. MAO is a flavoprotein located in the outer membrane of mitochondria and is presumed, though not proven, to contain Fe. The enzyme is believed to affect the concentration of neural mediators in the brain by regulating their rate of degradation. Indeed, some of the behavioral changes that follow administration of MAO inhibitors are similar to the restlessness and irritability described in severely iron deficient patients.

The delay in the response in CF test scores of the Fe treated group can also be supported by virtue of the biochemical basis for neural dysfunction.

Symes et al (1969) have shown that rats made Fe deficient had significantly lower tissue liver MAO activity in vitro when compared with normal animals. This finding was confirmed by measuring total MAO activity in vivo (Symes et al, 1971). These investigators showed that restoring iron to the diet of iron deficient rats restored MAO activity to normal one week later (Voorhess et al, 1975). However, Youdim et al (1975) studied the effect of oral iron treatment on hematological response and platelet MAO activity in a group of 7 iron deficient patients (5 females and 2 males). Four days after cessation of therapy (200 mg $FeSO_4$, thrice a day for 38 days) the serum iron concentration did not return to normal and the platelet MAO activity remained low.

This finding has a special bearing to the present study.

In the present study it was observed that although nearly 70% of the subjects had attained the Hb level of 12 g/dl or more, by the end of the second intervention, the SI value of only 9% subjects were greater than the normal value of 115 mcg/dl (INACG, 1981) and 89% subjects had values between 115 to 40 mcg/dl. INACG (1981) suggests that a SI value of less than 40 mcg/dl limits the production of Hb and leads to anemia; probably the needs of the erythroid marrow are not adequately met. Thus, a delay in response and a drop in scores for most CF tests could be attributed to the partially filled Fe stores, which would get further depleted on withdrawal of Fe therapy. Also, from the correlation coefficient between measures of iron status and selected CF test scores a poor relationship was observed. This may be due, in part, to the fact that the Fe stores were only partially filled.

Thus, to conclude, a beneficial effect of Fe supplementation on Cognitive Function test scores of underprivileged school girls, 8-15 years of age was indicated. The extent of benefit being larger in the anemics than in the non-anemics; in younger than in the older study population. No relationship between the measures of iron status and selected test scores of CF was observed because the normal values for these measures were not attained in the majority of the study population and visual motor coordination was sustained even four months after withdrawal of iron supplements, results indicated the need for long term oral iron therapy for the underprivileged school girls.

III. Impact of iron supplementation on Physical Work Capacity (PWC)

1. Impact of Fe supplementation on selected parameters of PWC in underprivileged school girls

Eighty-three pairs of subjects were strictly matched for the study of this function. The subjects were matched for age, initial Hb and body surface area. They were then randomly assigned to the two treatment groups, namely, Fe treated and placebo groups. The data on the matched sets is given in Table 4 in the chapter on Materials and Methods. The PWC was evaluated using the modified HST (mHST) as described earlier in the Materials and Methods chapter. The parameters for PWC used were the blood lactic acid and pulse rate, both pre and post exercise test at baseline (0 month), mid (4th month), final (8th month) and post-final (12th month) evaluations.

Table 34. Changes in pre and post exercise blood lactic acid[a] values on Fe supplementation over one year, in underprivileged school girls 8-15 yrs of age.

N=83	Hb (g/dl)	Blood lactic acid (mg/dl)	
		Pre exercise	post exercise
Baseline (B)	10.443±0.131	11.675±0.470	26.035±1.062
Mid (M)	11.669±0.12	9.775±0.305	19.525±0.48
Final (F)	12.381±0.086	8.659±0.222	16.808±0.346
Post-final (PF)	10.787±0.11	-	25.041±0.725
Paired 't' values			
B Vs M	13.41***	-4.41***	-6.82***
B Vs F	18.43***	-7.05***	-9.43***
B Vs PF	4.64***	-	-0.88[NS]
M Vs F	9.15***	-5.70***	-8.94***
M Vs PF	-9.42***	-	7.08***
F Vs PF	-17.03 ***	-	12.16***

[a]All values are mean ± SE

NS - Difference between the means non-significant

*** Difference between the means significant at $p < 0.001$.

Results of the blood lactate estimations

The blood lactate estimations were carried out pre and post exercise on the mHST at baseline (0 month), mid (4th month), final (8th month) and post-final (12th month) evaluations.

The data pertaining to the Fe treated group over the entire study period is set out in Table 34, and the corresponding values for the placebo group are indicated in Table 35. The data on the pre exercise blood lactate values at post-final evaluation could not be obtained on all subjects due to poor subject compliance, and thus, has been deleted for all subjects.

1. Within group comparison

The paired 't' test was employed to compare the blood lactate values of either treatment groups at baseline, mid, final and post-final evaluations. Comparisons made were similar to those for the changes in mean Hb values.

As evidenced in Table 34, a highly significant drop ($p \angle 0.001$) in the pre exercise (11.67 to 9.77 mg/dl) blood lactate values for the Fe treated group was obtained at mid evaluation. The values further dropped significantly ($p \angle 0.001$) at final evaluation, from those at mid evaluation; indicating a greater benefit of continued Fe therapy. The values at final evaluation were much lower than those at baseline.

Table 35. Changes in pre and post exercise blood lactic acid[a] values in the placebo group over one year, in underprivileged school girls, 8-15 yrs of age.

N=83	Hb (g/dl)	Blood lactic acid (mg/dl)	
		Pre exercise	Post exercise
Baseline (B)	10.410$\pm$0.125	11.187$\pm$0.544	24.716$\pm$0.870
Mid (M)	10.718$\pm$0.119	11.959$\pm$0.356	25.177$\pm$0.712
Final (F)	10.708$\pm$0.111	11.416$\pm$0.368	23.416$\pm$0.682
Post-final (PF)	10.391$\pm$0.101	-	23.528$\pm$0.630
Paired 't' value			
B Vs M	3.94***	1.51^{NS}	0.60^{NS}
B Vs F	3.87***	0.90^{NS}	-1.28^{NS}
B Vs PF	-0.37^{NS}	-	-1.06^{NS}
M Vs F	-0.27^{NS}	-1.44^{NS}	-4.03***
M Vs PF	-4.51***	-	-3.82***
F Vs PF	-4.48***	-	0.49^{NS}

[a]All values are mean $\pm$ SE

NS - Difference between means non-significant

*** Difference between means significant at $p \angle 0.001$

Table 36. Changes in pre and post exercise pulse rate[a] on Fe supplementation over one year, in underprivileged school girls, 8-15 yrs. of age.

N=83	Hb (g/dl)	Pulse rate beats/min	
		Pre exercise	Post exercise
Baseline (B)	10.443±0.131	94.674±1.259	175.253±1.926
Mid (M)	11.669±0.12	93.927±1.168	167.590±1.325
Final (F)	12.381±0.086	91.807±1.022	168.867±1.113
Post-final (PF)	10.7872±0.11	94.361±1.198	172.939±1.551
Paired 't' values			
B Vs M	13.41***	-1.65[NS]	-4.97***
B Vs F	18.43***	-4.06***	-5.09***
B Vs PF	4.64***	-0.98[NS]	-2.84**
M Vs F	9.15***	-4.26***	1.06[NS]
M Vs PF	-9.42***	1.19[NS]	4.27***
M Vs PF	-17.03***	3.99***	4.38***

[a]All values are mean ± SE

NS - Difference between means non-significant.
** Difference between means significant at p $\angle$ 0.01
*** Difference between means significant at p$\angle$ 0.001

A similar analysis for the post exercise blood lactate values indicated a highly significant drop in the values from baseline to mid and a further drop at final evaluation. At post-final evaluation, when the data was collected 4 months after withdrawal of Fe therapy, the post exercise blood lactate values had increased. This value was significantly ($p < 0.001$) greater than that at mid or at final evaluation. No difference, statistically, was observed between the baseline and post-final values, although, the value at post-final evaluation was lower than that at baseline.

The paired 't' test was repeated for the placebo group (Table 35). Results of this set of analysis indicated non-significant changes in the pre and post exercise blood lactate values at mid and final evaluations from those at baseline. Although, a trend for the drop was indicated. At post-final evaluation, the post exercise blood lactate values remained largely unchanged.

Results of pulse rate estimations

The pre and post exercise pulse rate values for the Fe treated group are indicated in Table 36.

Iron supplementation resulted in a highly significant benefit in the pre and post exercise pulse rate values. A highly significant drop in the post exercise pulse rate values was indicated in this group at mid evaluation. A further drop in the post exercise

Table 37. Changes in pre and post exercise pulse rates[a] in the placebo group over one year, in underprivileged school girls, 8-15 yrs. of age.

N=83	Hb (g/dl)	Pulse rate beats/min Pre exercise	Post exercise
Baseline (B)	10.410±0.125	96.674±1.085	178.915±2.170
Mid (M)	10.718±0.119	96.964±1.03	177.108±1.495
Final (F)	10.708±0.111	96.650±0.976	175.012±1.398
Post-final (PF)	10.391±0.101	96.193±1.037	178.193±1.589
Paired 't' values			
B Vs M	3.94***	1.65 NS	-1.35 NS
B Vs F	3.87***	-0.03 NS	-2.09*
B Vs PF	-0.37 NS	-0.81 NS	- 0.61 NS
M Vs F	-0.27 NS	-0.45 NS	- 1.71 NS
M Vs PF	-4.51***	-1.31 NS	1.11 NS
F Vs PF	-4.48***	-0.54 NS	2.04*

[a]All values are mean ± SE

NS - Difference between means non-significant

* Difference between means significant at $p < 0.05$

*** Difference between means significant at $p < 0.001$

pulse rate values was indicated at final evaluation. On withdrawal of therapy, the post exercise pulse rate increased significantly from the final values (173 to 169 beats/min), though remaining significantly lower than the baseline pulse rate (173 Vs 175 beats/min).

The changes in the pre exercise pulse rate values were not as clearcut as the post exercise values. A significant drop in the pre exercise values from those at baseline was observed only at final evaluation; at mid evaluation, only a slight drop was observed. On withdrawal of Fe therapy the pulse rate values reverted to those at baseline, increasing significantly from the final values.

Similar analysis for the placebo group (Table 37) indicated no change throughout the study period in the pre-exercise values. However, the post exercise values had dropped slightly from those at baseline; the values at final evaluation being significantly ($p \angle 0.05$) lower than those at baseline. On withdrawal of therapy, the pulse rate values had increased and did not differ significantly from the baseline values.

The changes in the post-exercise blood lactate and pulse rate values in the placebo group could be attributed to the fact that, practice on the bench made the exercise task more familiar and possibly a little easier for the subjects. Since, this group functioned as the control, it would not be incorrect to presume a

Table 38. Baseline data of pre and post-exercise pulse rate[a] and blood lactic acid[a] values in the Fe treated Vs. placebo group subjects.

Groups	Pulse rate beats/min		Blood lactic acid (mg/dl)	
	Pre-exercise	Post-exercise	Pre-exercise	Post-exercise
Fe treated group (83)	94.674 ± 1.259	175.253 ± 1.926	11.675 ± 0.47	26.035 ± 1.062
Placebo group (83)	96.674 ± 1.085	178.915 ± 2.17	11.186 ± 0.544	24.716 ± 0.87
't' values	1.20^{NS}	1.26^{NS}	0.68^{NS}	0.96^{NS}

[a]All values are mean ± SE

NS - Difference between the mean non-significant

Table 39. Pre and post exercise pulse rate[a] and blood lactic acid[a] values in the Fe treated versus placebo group subjects at mid evaluation.

Groups	Pulse rate beats/min		Blood lactic acid (mg/dl)	
	Pre-exercise	Post-exercise	Pre-exercise	Post-exercise
Fe treated group (83)	93.927 ± 1.168	167.590 ± 1.325	9.775 ± 0.305	19.525 ± 0.480
Placebo group (83)	96.964 ± 1.030	177.108 ± 1.495	11.959 ± 0.356	25.177 ± 0.712
't' values	-1.95^{NS}	-4.76***	-4.65***	-6.58***

[a] All values are mean $\pm$ SE

NS - Difference between the means non-significant

*** Difference between the means significant at $p < 0.001$

Table 40. Pre and post exercise pulse rate [a] and blood lactic acid[a] values in the Fe treated versus placebo group subjects at final evaluation.

Groups	Pulse rate beats/min		Blood lactic acid (mg/dl)	
	Pre-exercise	Post-exercise	Pre-exercise	Post-exercise
Fe treated group (83)	91.807±1.022	168.867±1.113	8.659±0.222	16.808±0.346
Placebo group (83)	96.650±0.976	175.012±1.398	11.416±0.368	23.416±0.682
't' values	-3.43***	-3.44***	-6.41***	-8.64***

[a] All values are mean ± SE

*** Difference between means significant at $p < 0.001$

similar effect in the Fe treated group also. It thus became necessary to compare the two groups to obtain the true effect of Fe supplementation.

The true benefit of Fe therapy could be asserted by a significantly greater benefit in the Fe treated group than that in the placebo group.

2. Between group comparison

In order to make comparison between the Fe treated versus the placebo group, the independent 't' test was employed.

Comparisons were made at baseline, mid, final and post-final evaluations for each parameter.

The results of this analysis indicated that the two groups were similar to start with at baseline (Table 38) in all parameters tested. This was a result of the stringent matching of the two groups in the beginning of the study.

The benefit of Fe supplementation showed up at mid evaluation (Table 39) in the pre and post exercise blood lactate and only in the post-exercise pulse rate values. This was indicated by significantly ($p \angle 0.001$) lower values for the Fe treated group. At final evaluation, the benefit in the Fe treated group was even greater, which was indicated by lower values for all parameters, including the pre-exercise pulse rate values, than the placebo group (Table 40).

Table 41. Pre and post exercise pulse rate[a] and blood lactic acid[a] values in the Fe treated versus placebo group subjects at post-final evaluation.

Groups	Pulse rate beats/min		Blood lactic acid (mg/dl)	
	Pre-exercise	Post-exercise	Pre-exercise	Post-exercise
Fe treated group (83)	94.361$\pm$1.198	172.939$\pm$1.551	-	25.041$\pm$0.725
Placebo group (83)	96.193$\pm$1.037	178.193$\pm$1.589	-	23.528$\pm$0.630
't' values	-1.16^{NS}	-2.37**	-	1.58^{NS}

[a]All values are mean $\pm$ SE

NS - Difference between the means non-significant

** Difference between means significant at $p \angle 0.01$

FIG. 18 CHANGES IN THE PRE AND POST EXCERCISE PULSE RATE VALUES IN THE Fe TREATED VERSUS PLACEBO GROUP AT BASELINE (B), MID (M), FINAL (F) AND POST-FINAL (PF) EVALUATIONS OF THE STUDY

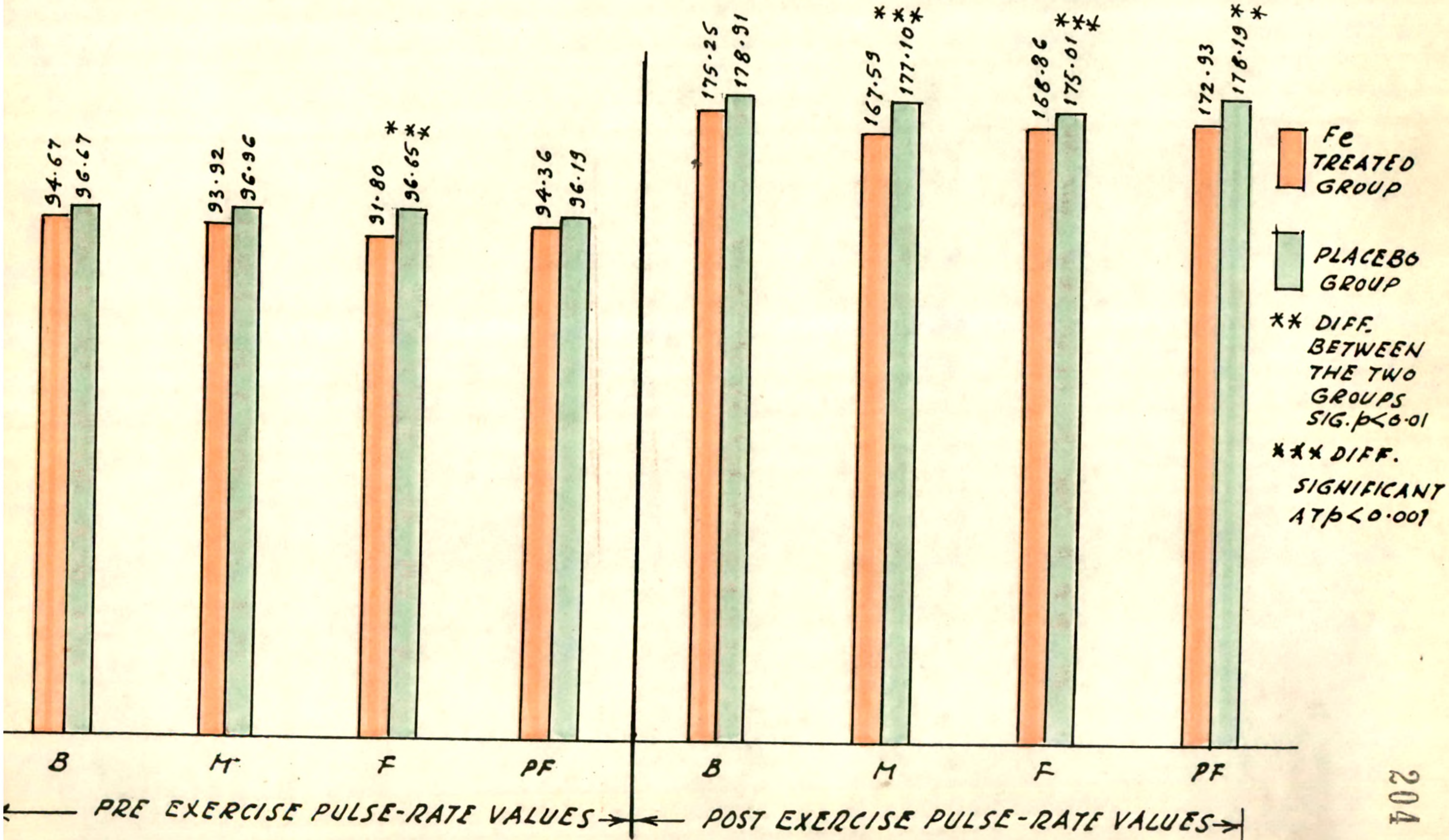
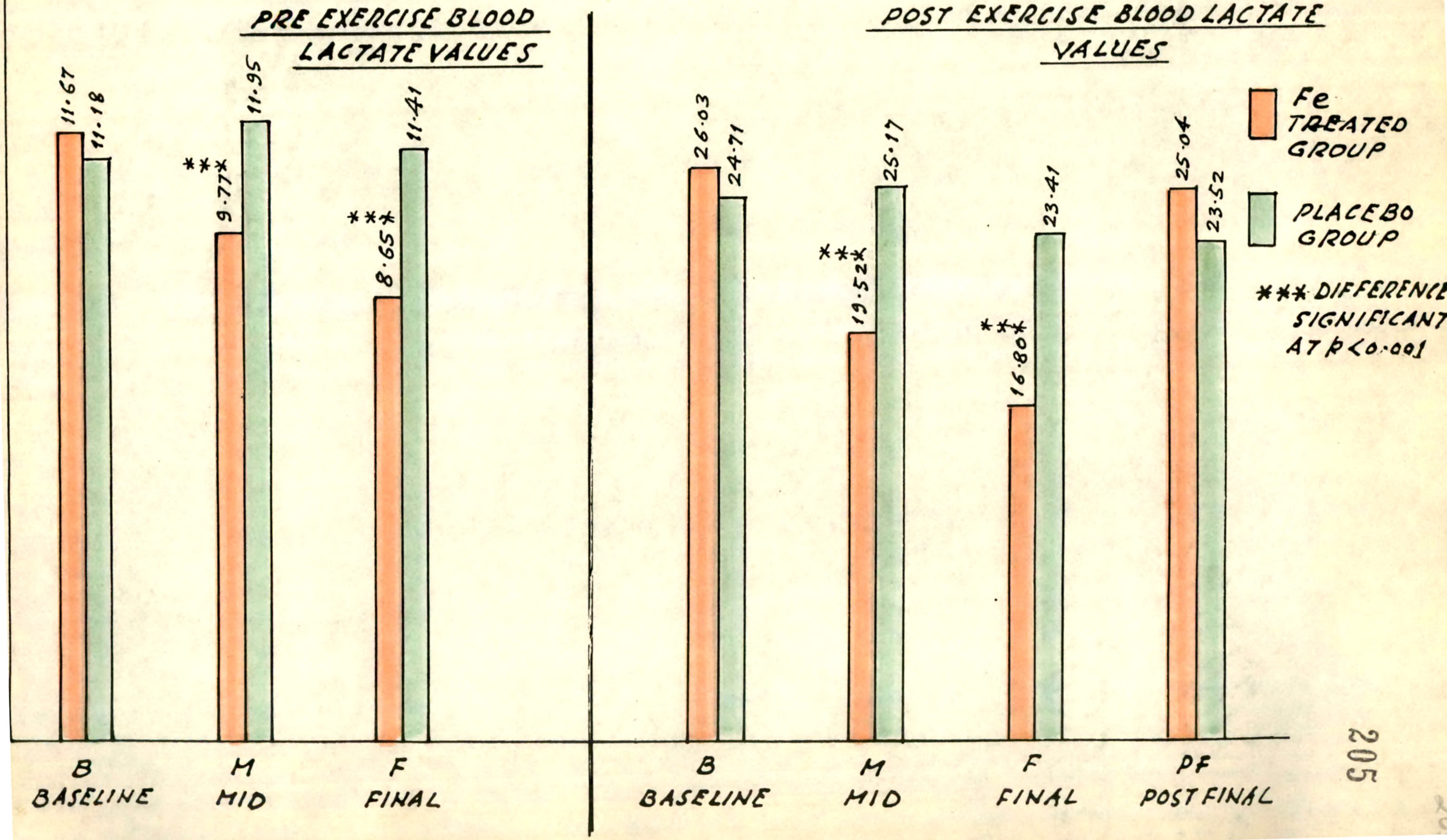


FIG. 19 CHANGES IN THE PRE AND POST EXERCISE BLOOD LACTIC ACID VALUES IN THE Fe TREATED VERSUS PLACEBO GROUP AT BASELINE (B), MID (M), FINAL (F) AND POST FINAL (PF) EVALUATIONS OF THE STUDY



The comparison between the two groups at post-final evaluation is presented in Table 41. No significant difference between the two groups was observed in the pre-exercise pulse rate or post-exercise blood lactate values. However, the post-exercise pulse rate values were significantly ($p < 0.001$) lower in the Fe treated than in the placebo group.

Results of Tables 38 to 41 and Fig 18 and 19 indicate a beneficial effect of Fe supplementation by an increased Hb and a concomitant lowering of blood lactate and pulse rate values, at rest and in response to exercise. However, the blood lactate estimation emerged as a more sensitive parameter than the pulse rate, as the impact of supplementation was evidenced immediately (mid evaluation) after Fe therapy by this parameter. Also, as soon as the Hb values dropped (at post-final evaluation) a change in blood lactate values was also observed.

As evident from Table 36 the beneficial effect of Fe supplementation was not sustained in measures of PWC on withdrawal of therapy for 4 months.

2. Relationship between iron status and PWC

An attempt to evaluate the relationship between iron status and various parameters of PWC was made. The measures of iron status studied were Hb, SI, TIBC and TS in relation to the pre and post-exercise blood lactate and pulse rate values.

Table 42. Correlation matrix for Fe status and parameters of PWC in the Fe treated subjects.

	Hb (B) (83)	Hb (M) (83)	Hb (F) (83)	Hb (PF) (83)	SI (48)	TIBC (48)	% Sat (48)
PR (B+) B	-.2292* 0.019	-	-	-	-	-	-
PR (A+) B	-.5023*** 0.001	-	-	-	-	-	-
PR (B+) M	-	-0.0467 0.337	-	-	-	-	-
PR (A+) M	-	-0.0886 0.213	-	-	-	-	-
PR (B+) F	-0.1995 0.035*	-	-.1093 0.163	-	-.1196 0.209	.2429* 0.048	-.1864 0.102
PR (A+) F	-0.4567*** 0.001		-.3731*** 0.001		-.3559 0.007	.3326** 0.01	-.4102** 0.002
PR (B+) PF	-	-	-	-.2378* 0.015	-	-	-
PR (A+) PF	-	-	-	-.3714*** 0.001	-	-	-
BLA (B+) B	-.1216 0.137	-	-	-	-	-	-
BLA (A+) B	-.2805** 0.005	-	-	-	-	-	-
BLA (B+) M	-	-.2205* 0.023	-	-	-	-	-
BLA (A+) M		-.2037* 0.032	-	-	-	-	-
BLA (B+) F	-0.3855 0.001***	-	-.3831 0.001***	-	-.2034 0.083	.3578 0.006**	-.3227* 0.013
BLA (A+) F	-0.5017*** 0.001	-	-.4582 0.001	-	-.2866* 0.024	.3710** 0.005	-.3569 0.001***
BLA (B+) PF	-	-	-	-	-	-	-
BLA (A+) PF	-	-	-.8661 0.001***	-	-	-	-

* Values significant at $p \angle 0.05$. ** Values significant at $p \angle 0.01$. *** Values significant at $p \angle 0.001$

B-Baseline, M-Mid evaluation, F - Final evaluation, PF - Post-final evaluation.

B+ - Pre-exercise, A+ - post-exercise

The correlation coefficient (r) was calculated for Hb at baseline, mid, final and post-final evaluations, and SI, TIBC and TS values at final evaluation with the respective pre and post-exercise blood lactate and pulse rate values.

Results of the correlation coefficient (r) (Table 42), indicated a significant inverse correlation between the Hb values and the post-exercise blood lactate values at baseline ($r = -0.2805$; $p < 0.05$, at mid ($r = -0.2037$; $p < 0.05$), at final ($r = -0.4582$; $p < 0.001$) and at post-final ($r = -0.8661$; $p < 0.001$) evaluations. The relationship between Hb and the pre-exercise blood lactate values was not so clearcut; showing no relationship at baseline; a correlation coefficient of $r = -0.2205$ at mid and $r = 0.3831$ at final evaluations, significant at 5% and 1% levels respectively.

The negative value of r was an indicator of an inverse relationship between the two, i.e. a decrease in the blood lactate values was observed as the Hb values increased.

An interesting relationship between the initial Hb and final blood lactate values, both pre and post-exercise was observed. The results of the correlation analysis indicated a highly significant ($p < 0.001$) inverse relationship between the initial Hb and pre-exercise blood lactate ($r = -0.3855$) and post-exercise blood lactate ($r = -0.5117$) values at final evaluation.

The correlation coefficient was determined between the pre and post-exercise blood lactate, and SI, TIBC and TS values. An inverse relationship for the pre and post-exercise blood lactate values, and SI and TS, and a positive correlation with TIBC values was indicated. The post-exercise blood lactate values correlated with SI ($r = -0.2866$; $p < 0,005$), TIBC ($r = 0.3710$; $p < 0.01$) and TS ($r = -0.3569$; $p < 0.001$) values. The results for the pre-exercise blood lactate values were not so distinct; showing no relationship with the SI values, a slight correlation with TIBC ($r = 0.3578$; $p < 0.01$) and TS ($r = -0.3227$; $p < 0.05$) values.

Similar tests of correlation were carried out for both pre and post-exercise pulse rate values.

The analysis indicated a highly significant inverse correlation ($p < 0.001$) between the Hb at baseline, final and post-final evaluations with their respective post-exercise pulse rate values. The correlation between Hb and the pre-exercise pulse rate were observed only at baseline ($p < 0.05$) and post-final ($p < 0.05$) evaluations. A highly significant inverse relationship between initial Hb and final post-exercise pulse rate ($r = 0.4567$; $p < 0.001$) and a significant relationship between Hb with the final pre-exercise pulse rate ($r = - 0.1995$; $p < 0.05$) were observed. Also, the correlation with SI, TIBC and TS were observed only with the post-exercise pulse rate values.

From the above results, it is evident that the iron status has as important bearing on an individual's ability to perform physical work. On supplementation with Fe, a beneficial effect on the iron status (represented by Hb, SI, TIBC and TS values) and concomitant lowering of blood lactate and pulse rate, at rest and in response to exercise was observed. The benefit is transient and lasts only till the Hb values are high as evidenced by an increase in these values, reverting to those at baseline, on withdrawal of Fe therapy for 4 months.

3. Impact of Fe supplementation on anemic and non-anemic subjects

As illustrated in the previous section (III.2), there is a significant correlation between Hb values and measures of PWC. However, it would be interesting to study the changes in these aspects of PWC on subjects, considering only the polar ends of Hb values i.e. anemics and non-anemics, both within and between the two treatment groups.

For this purpose the subjects were divided into two categories based on their baseline Hb values and then followed up. The two categories were :

Table 43. Changes in pre and post-exercise blood lactic acid[a] values on Fe supplementation in the anemic (Hb $\leqslant$ 10.5 g/dl) subjects over one year.

N=41	Hb (g/dl)	Blood lactic acid (mg/dl)	
		Pre-exercise	Post-exercise
Baseline (B)	9.494 ± 0.122	12.103 ± 0.612	$29.262 + 1.261$
Mid (M)	11.022 ± 0.166	10.183 ± 0.447	20.455 ± 0.672
Final (F)	11.958 ± 0.119	9.485 ± 0.302	18.259 ± 0.397
Post-final (PF)	10.130 ± 0.130	-	29.093 ± 0.883
Paired 't' values			
B Vs M	11.27***	-3.30**	-6.10***
B Vs F	18.17***	-4.71***	-8.27***
B Vs PF	6.21***	-	-0.10[NS]
M Vs F	7.39***	-2.38*	-5.06***
M Vs PF	- 6.09***	-	7.57***
F Vs PF	-13.70***	-	11.06***

[a]All values are mean $\pm$ SE

NS - Difference between means non-significant
* Difference between means significant at $p \angle 0.05$
** Difference between means significant at $p \angle 0.01$
*** Difference between means significant at $p \angle 0.001$

anemics - subjects with Hb $\leq$ 10.5 g/dl and

non-anemics - subjects with Hb $\geq$ 11.5 g/dl at baseline evaluation.

Those subjects having intermediate Hb values were deleted for this particular analysis.

The final sample size was reduced to 41 anemic and 16 non-anemic subjects in the Fe treated group and 45 anemic and 10 non-anemic subjects in the placebo group. The within group comparisons were made using the paired 't' test as for II, and the between group comparisons were made using the independent 't' test for both blood lactate and pulse rate values at pre and post-exercise for both the treatment groups.

Anemics

1 Within group comparison

Changes in the pre and post-exercise blood lactate values of the Fe treated anemic subjects are indicated in Table 43.

Results indicated a highly significant improvement in Hb values at mid and final evaluation in this group. An associated improvement in the blood lactate values was observed as the Hb values improved. A significant drop was observed in both the pre and post-exercise blood lactate values, from 12.10 to 10.18 to 9.48 mg/dl and 29.26 to 20.45 to 18.26 mg/dl respectively, in the Fe treated group. The benefit in the post-exercise values was

Table 44. Changes in the pre and post-exercise blood lactic acid[a] values of the anemic ($Hb \leqslant 10.5$ g/dl) subjects in the placebo group over one year.

N=45	Hb (g/dl)	Blood lactic acid (mg/dl)	
		Pre-exercise	Post exercise
Baseline (B)	9.611±0.113	10.414±0.732	26.273±1.275
Mid (M)	9.993±0.104	12.253±0.450	27.459±1.026
Final (F)	10.022±0.097	11.235±0.462	25.554±0.930
Post-final (PF)	9.765±0.084	-	25.580±0.860
Paired 't' values			
B Vs M	3.29**	2.66*	1.14^{NS}
B Vs F	3.57***	1.56^{NS}	-0.66^{NS}
B Vs PF	2.01^{NS}	-	-0.63^{NS}
M Vs F	0.66^{NS}	-2.7*	-4.81***
M Vs PF	-2.33*	-	-4.67***
F Vs PF	-2.59*	-	0.08^{NS}

[a]All values are mean ± SE

NS - Difference between means non-significant
* Difference between means significant at $p < 0.05$
** Difference between means significant at $p < 0.01$
*** Difference between means significant at $p < 0.001$

Table 45. Changes in pre and post-exercise pulse rate[a] values on Fe supplementation in the anemic (Hb $\leqslant$ 10.5 g/dl) subjects over one year.

N=41	Hb (g/dl)	Blood lactic acid (mg/dl)	
		Pre-exercise	Post-exercise
Baseline (B)	9.494 ± 0.122	97.463 ± 1.712	184.537 ± 2.312
Mid (M)	11.022 ± 0.166	96.146 ± 1.488	169.756 ± 1.946
Final (F)	11.958 ± 0.119	93.951 ± 1.318	174.00 ± 1.451
Post-final (PF)	10.130 ± 0.130	97.415 ± 1.576	179.561 ± 1.855
Paired 't' values			
B Vs M	11.27***	-2.68*	-6.36***
B Vs F	18.17***	-4.07***	-5.85***
B Vs PF	6.21***	-0.14 NS	-3.76***
M Vs F	7.39***	-3.76***	1.95 NS
M Vs PF	-6.09***	2.92**	4.62***
F Vs PF	- 13.70***	4.43***	3.67***

[a] All values are mean ± SE

NS - Difference between means non-significant
* Difference between means significant at $p < 0.05$
** Difference between means significant at $p < 0.01$
*** Difference between means significant at $p < 0.001$

much more marked than that in the pre-exercise blood lactate values. On withdrawal of Fe therapy the post-exercise blood lactate values retrogressed to the baseline values. Although, this value was lower than baseline value, the difference was non-significant.

The paired 't' test analysis was repeated for the anemic placebo group. The results of this analysis (Table 44) indicated a significant ($p < 0.05$) increase in the pre-exercise (10.41 to 12.25 mg/dl) and a non-significant increase in the post-exercise (26.27 to 27.46 mg/dl) blood lactate values, at mid evaluation. However, asthe study progressed, the values dropped slightly at final evaluation (11.23 and 25.5 mg/dl for pre and post-blood lactate values but remained inappreciably lower than those at baseline.

Results of the paired 't' test for the pulse rate, for the Fe treated and placebo groups are presented in Tables 45 and 46 respectively.

The analysis for the Fe treated anemics (Table 45) indicated a highly significant ($p < 0.001$) benefit in the post-exercise pulse rate values at mid and at final evaluations. Although, an increase in the post-exercise pulse rate was observed on withdrawal of Fe therapy, this value was significantly lower than that at baseline, a difference of nearly 5 beats/min. The changes in the pre-exercise pulse rate values were not as marked as those in the post-exercise

Table 46. Changes in the pre and post-exercise pulse rate[a] values of the anemic (Hb $\leq$ 10.5 g/dl) placebo group subjects over one year.

N=45	Hb (g/dl)	Blood lactic acid (mg/dl)	
		Pre-exercise	Post-exercise
Baseline (B)	9.611±0.113	98.400±1.313	184.80±2.332
Mid (M)	9.993±0.104	98.667±1.229	181.20±1.636
Final (F)	10.022±0.097	98.133±1.064	178.267±1.422
Post-final (PF)	9.765±0.084	96.444±0.261	181.333±1.694
Paired 't' values			
B Vs M	3.29**	1.43NS	-2.39*
B Vs F	3.57***	-0.20NS	-2.35*
B Vs PF	2.01NS	-2.55*	-2.64*
M Vs F	0.66NS	-0.41NS	-1.35NS
M Vs PF	-2.33*	-2.96**	0.12NS
F Vs PF	-2.59*	-1.26NS	1.30NS

[a]All values are mean ± SE

NS - Difference between means non-significant
* Difference between means significant $p < 0.05$
** Difference between means significant $p < 0.01$
*** Difference between means significant $p < 0.001$

values. A drop in the pre-exercise values was about 1 beat/min as against the drop of 15 beats/min in the post-exercise pulse rate values at mid evaluation. Similarly, at final evaluation, the pre-exercise values were lower than the baseline values by about 4 beats/min as against 10 beats/min in the post-exercise pulse rate values.

The paired 't' test analysis for the placebo group for the changes in the pre and post-exercise pulse rate values is indicated in Table 46. Results indicated a trend similar to that for blood lactate values. Non-significant changes in the pre-exercise pulse rate at mid and at final evaluation were observed. However, the pre-exercise pulse rate value at post-final evaluation was significantly lower than the values at baseline ($p < 0.05$) and at mid ($p < 0.01$) evaluations.

Significant changes in the post-exercise pulse rate values were observed at mid ($p < 0.05$), atfinal ($p < 0.05$) and at post-final ($p < 0.05$) evaluations in the placebo group.

As evident from Tables 43, 44, 45 and 46, changes were observed in both the treatment groups (Fe and placebo). However, it was important to establish the magnitude of difference in the two groups. Thus, a comparison was made between the two groups at all four points of time.

Table 47. Comparison of pre and post-exercise pulse rate[a] and blood lactic acid[a] values in the Fe treated versus placebo group anemic subjects at baseline evaluation.

Groups	Hb (g/dl)	Pulse rate beats/min		Blood lactic acid (mg/dl)	
		Pre-exercise	Post-exercise	Pre-exercise	Post-exercise
Fe treated anemics (41)	9.494 ±0.122	97.463 ±1.712	184.537 ±2.312	12.103 ±0.612	29.262 ±1.261
Placebo anemics (45)	9.611 ±0.113	98.40 ±1.313	184.80 ±2.332	10.414 ±0.732	26.273 ±1.275
't' values	0.7048[NS]	0.4343[NS]	0.0800[NS]	1.7702[NS]	1.6668[NS]

[a]All values are mean ± SE

NS - Difference between means non-significant.

Anemics - Hb $\leq$ 10.5 g/dl at baseline.

Table 48. Comparison of pre and post-exercise pulse rate[a] and blood lactic acid values[a] in the Fe treated versus placebo group anemic subjects at mid evaluation.

Groups	Hb (g/dl)	Pulse rate beats/min		Blood lactic acid (mg/dl)	
		Pre-exercise	Post exercise	Pre-exercise	Post-exercise
Fe treated (41)	11.022 $\pm$0.166	96.146 $\pm$1.488	169.756 $\pm$1.946	10.183 $\pm$0.447	20.455 $\pm$0.672
Placebo group (45)	9.993 $\pm$0.104	98.667 $\pm$1.229	181.20 $\pm$1.636	12.253 $\pm$0.450	27.459 $\pm$1.026
't' values	5.258***	1.3062[NS]	11.444***	2.07*	5.711***

[a]All values are mean $\pm$ SE

NS - Difference between means non-significant

* Difference between means significant at $p < 0.05$

*** Difference between means significant at $p < 0.001$

Anemics - Hb $\leqslant$ 10.5 g/dl at baseline.

Table 49. Comparison of pre and post-exercise pulse rate[a] and blood lactic acid[a] values in the Fe treated versus placebo group anemic subjects at final evaluation.

Group	Hb (g/dl)	Pulse rate beats/min		Blood lactic acid (mg/dl)	
		Pre-exercise	Post-exercise	Pre-exercise	Post-exercise
Fe treated (41)	11.958 ±0.119	93.951 ±1.318	174.00 ±1.451	9.485 ±0.302	18.259 ±0.397
Placebo group (45)	10.022 ±0.097	98.133 ±1.064	178.267 ±1.422	11.235 ±0.462	25.554 ±0.930
't' values	12.6288***	2.469*	2.1003*	3.1708**	7.2149***

[a] All values are mean ± SE

* Difference between means significant at $p < 0.05$

** Difference between means significant at $p < 0.01$

*** Difference between means significant at $p < 0.001$

Anemics - Hb $\leq$ 10.5 g/dl at baseline.

Table 50. Comparison of pre and post-exercise pulse rate[a] and blood lactic acid[a] values in the Fe treated versus placebo group anemic subjects at post-final evaluation.

Groups	Hb (g/dl)	Pulse rate beats/min		Blood lactic acid (mg/dl)	
		Pre-exercise	Post-exercise	Pre-exercise	Post-exercise
Fe treated (41)	10.130 ±0.130	97.415 ±1.576	179.561 ±1.855	-	29.093 ±0.883
Placebo group (45)	9.765 ±0.084	96.444 ±1.261	181.333 ±1.694	-	25.580 ±0.806
't' values	0.8700[NS]	0.4810[NS]	0.7054[NS]	-	2.9385**

[a]All values are mean ± SE

NS - Difference between means non-significant

** - Difference between means significant at $p < 0.01$

Anemics - Hb $\leq$ 10.5 g/dl at baseline

2 Between group comparison

A comparison of the anemic iron treated with the placebo treated subjects was made using the independent 't' test at baseline, mid, final and post-final evaluations. The results for these comparisons are indicated in Tables 47 to 50.

Results of the independent 't' test indicated no difference between the anemic subjects in the two treatment groups at baseline evaluation in any of the parameters tested. Thus, the changes observed in subsequent testing could be attributed to the treatment effect. Tables 48 and 49 indicate the changes in pre and post-exercise blood lactate and pulse rate values at mid and final evaluations respectively.

At mid evaluation, the Fe treated group had significantly lower post-exercise ($p < 0.001$) and pre-exercise ($p < 0.05$) blood lactate values and significantly ($p < 0.001$) lower post-exercise pulse rate values, than the placebo group. However, at final evaluation, the significant benefit was observed in the pre-exercise ($p < 0.01$) and post-exercise ($p < 0.001$) blood lactate values and in the pre and post-exercise pulse rate values ($p < 0.05$).

On comparing the withdrawal data of the anemics for the two treatment groups, the placebo group showed significantly lower ($p < 0.01$) post-exercise blood lactate values than the iron treated group. However, both these values were similar to their respective baseline values.

Table 51. Changes in pre and post-exercise blood lactic acid[a] values on Fe supplementation in the non-anemic subjects over one year.

N = 16	Hb (g/dl)	Blood lactic acid (mg/dl)	
		Pre-exercise	Post-exercise
Baseline (B)	12.094±0.12	10.652±0.943	22.516±2.593
Mid (M)	12.762±0.161	8.821±0.462	17.296±1.013
Final (F)	13.013±0.15	7.622±0.380	13.979±0.643
Post-final (PF)	11.883±0.171	-	17.702±1.221
Paired 't' values			
B Vs M	3.42**	-2.02NS	-2.87*
B Vs F	4.76***	-3.47**	-3.88**
B Vs PF	-1.57NS	-	-1.85NS
M Vs F	, 2.59*	-5.36***	-5.22***
M Vs PF	-4.04**	-	0.28NS
F Vs PF	-5.06***	-	2.66*

[a]All values are mean ± SE

NS - Difference between means non-significant.

* Differencebetweem means significant at $p < 0.05$

** Difference between means significant at $p < 0.01$

*** Difference between means significant at $p < 0.001$

Non-anemics - Hb $\geq$ 11.5 g/dl at baseline.

Non-anemics

The impact of supplementation on the non-anemic subjects in the two treatment groups was studied. Comparisons were made both within and between the two treatment groups, as for the anemic subjects.

1 Within group comparisons

Blood lactate

Table 51 gives the changes in the pre and post-exercise blood lactate values on Fe supplementation over the entire study period.

Results of the paired 't' test indicated a non-significant drop in the pre-exercise blood lactate values at mid evaluation. At final evaluation, the values dropped further and were significantly lower than those at baseline evaluation.

Iron supplementation resulted in a significant benefit in the post-exercise blood lactate values, both at mid ($p < 0.05$) and at final ($p < 0.01$) evaluations. On withdrawal of supplements the values increased significantly from those at final evaluation. Although, this value was lower than that at baseline, the difference was non-significant.

Table 52. Changes in pre and post-exercise blood lactic acid[a] values in the non-anemic placebo group subjects over one year.

N=10	Hb (g/dl)	Blood lactic acid (mg/dl)	
		Pre-exercise	Post-exercise
Baseline (B)	12.307±0.195	11.640±1.534	24.110±1.618
Mid (M)	12.317±0.147	10.480±1.089	21.617±0.999
Final (F)	12.194±0.191	11.760±1.103	21.754±1.297
Post-final (PF)	11.855±0.231	-	20.999±1.119
Paired 't' values			
B Vs M	0.07^{NS}	-1.05^{NS}	-1.41^{NS}
B Vs F	-0.75^{NS}	0.14^{NS}	-1.34^{NS}
B Vs PF	-7.25***	-	-1.92^{NS}
M Vs F	-1.14^{NS}	1.99^{NS}	0.12^{NS}
M Vs PF	-3.32**	-	-0.96^{NS}
F Vs PF	-2.20^{NS}	-	-1.04^{NS}

[a]All values are mean ± SE

NS - Difference between means non-significant

** Difference between means significant at $p < 0.01$

*** Difference between means significant at $p < 0.001$

Non-anemics - Hb $\geq$ 11.5 g/dl at baseline.

Table 53. Changes in pre and post-exercise pulse rate[a] values on Fe supplementation in the non-anemic subjects over one year.

N=16	Hb (g/dl)	Pulse rate (beats/min)	
		Pre-exercise	Post-exercise
Baseline (B)	12.094 ± 0.12	91.625 ± 2.800	164.750 ± 3.219
Mid (M)	12.762 ± 0.161	91.625 ± 2.800	166.125 ± 2.553
Final (F)	13.013 ± 0.150	90.375 ± 2.478	162.375 ± 1.855
Post-final (PF)	11.883 ± 0.171	91.250 ± 2.676	165.50 ± 2.872
Paired 't' values			
B Vs M	3.42**	-	0.75^{NS}
B Vs F	4.76***	-2.08^{NS}	-1.18^{NS}
B Vs PF	-1.57^{NS}	-1.0^{NS}	1.0^{NS}
M Vs F	2.59*	-2.08^{NS}	-2.61*
M Vs PF	-4.04**	-1.0^{NS}	-0.39^{NS}
F Vs PF	-5.06***	1.70^{NS}	1.95^{NS}

[a]All values are mean $\pm$ SE

NS - Difference between means non-significant

* Difference between means significant at $p < 0.05$

** Difference between means significant at $p < 0.01$

*** Difference between means significant at $p < 0.001$

Non-anemics - Hb $\geq$ 11.5 g/dl at baseline.

Table 54. Changes in pre and post-exercise pulse rate[a] values in the non-anemic placebo group subjects over one year.

N=10	Hb (g/dl)	Pulse rate (beats/min) pre-exercise	Pulse rate (beats/min) Post-exercise
Baseline (B)	12.307±0.195	86.80±2.829	157.80±5.219
Mid (M)	12.317±0.147	87.20±2.636	163.20±4.454
Final (F)	12.194±0.191	87.00±2.72	160.200±4.903
Post-final (PF)	11.855±0.231	89.00±3.518	164.400±4.214
Paired 't' values			
B Vs M	0.07^{NS}	1.00^{NS}	2.38*
B Vs F	-0.75^{NS}	0.38^{NS}	0.77^{NS}
B Vs PF	-7.25***	1.00^{NS}	0.240*
M Vs F	-1.14^{NS}	-0.29^{NS}	-1.25^{NS}
M Vs PF	-3.32**	0.71^{NS}	0.35^{NS}
F Vs PF	-2.20^{NS}	0.75^{NS}	1.17^{NS}

[a] All values are mean ± SE

NS - Difference between means non-significant

* Difference between means significant at $p < 0.05$

** Difference between means significant at $p < 0.01$

*** Difference between means significant at $p < 0.001$

Non-anemics - Hb ≥ 11.5 g/dl at baseline.

Table 55. Comparison of pre and post-exercise pulse rate[a] and blood lactic acid[a] values of non-anemic, Fe treated versus placebo group subjects at baseline.

Groups	Hb (g/dl)	Pulse rate (beats/min)		Blood lactic acid (mg/dl)	
		Pre-exercise	Post-exercise	Pre-exercise	Post-exercise
Fe treated (16)	12.094 $\pm$0.12	91.625 $\pm$2.80	164.750 $\pm$3.219	10.652 $\pm$0.943	22.516 $\pm$2.593
Placebo group (10)	12.307 $\pm$0.195	86.80 $\pm$2.829	157.80 $\pm$5.219	11.640 $\pm$1.534	24.110 $\pm$1.618
't' values	0.9305[NS]	1.2122[NS]	1.1334[NS]	0.5487[NS]	0.5215[NS]

[a]All values are mean $\pm$ SE

NS - Difference between means non-significant.

Non-anemics - Hb $\geqslant$ 11.5 g/dl at baseline.

Table 56. Comparison of pre and post-exercise pulse rate[a] and blood lactic acid[a] values of the non-anemic, Fe treated versus placebo group subjects at mid evaluation.

Groups	Hb (g/dl)	Pulse rate (beats/min)		Blood lactic acid (mg/dl)	
		Pre-exercise	Post exercise	Pre-exercise	Post-exercise
Fe treated (16)	12.762 ±0.161	91.625 ±2.80	166.125 ±2.553	8.821 ±0.462	17.296 ±1.013
Placebo group (10)	12.317 ±0.147	87.20 ±2.636	163.20 ±4,454	10.480 ±1.089	21.617 ±0.999
't' values	2.0422[NS]	1.1508[NS]	0.5697[NS]	1.4024[NS]	3.0371**

[a]All values are mean ± SE

NS - Difference between means non-significant

** Difference between means significant at $p < 0.01$

Non-anemics - Hb $\geq$ 11.5 g/dl at baseline.

Table 57. Comparison of pre and post-exercise pulse rate[a] and blood lactic acid[a] values of the non-anemic, Fe treated versus placebo group subjects at final evaluation.

Groups	Hb (g/dl)	Pulse rate (beats/min)		Blood lactic acid (mg/dl)	
		Pre-exercise	Post-exercise	Pre-exercise	Post-exercise
Fe treated (16)	13.013 $\pm$0.15	90.375 $\pm$2.478	162.375 $\pm$1.855	7.622 $\pm$0.380	13.979 $\pm$0.643
Placebo group (10)	12.194 $\pm$0.191	87.00 $\pm$2.72	160.20 $\pm$4.903	11.760 $\pm$1.103	21.754 $\pm$1.297
't' values	3.373**	0.9172[NS]	0.4149[NS]	3.547**	5.3709**

[a]All values are mean $\pm$ SE

NS - Difference between means non-significant

** Difference between means significant at $p \angle 0.01$

*** Difference between means significant at $p \angle 0.001$

Non-anemics - Hb $\geqslant$ 11.5 g/dl at baseline.

A similar analysis for the placebo group indicated no significant change over the entire study period (Table 52) either in the pre or post-exercise blood lactate values, only a trend of lowered values on subsequent testing was observed.

Pulse rate

No significant alterations in the pre andpost-exercise pulse rates were observed on iron supplementation (Table 53). In the placebo group also, non-significant changes in the pre-exercise pulse rate values were observed. However, the post-exercise pulse rate values were significantly ($p \angle 0.05$) higher at mid and post-final evaluations than those at baseline. The difference between the baseline and final values was non-significant (Table 54).

2 Between group comparison

Comparison of the pre and post-exercise blood lactate and pulse rate values, between the two treatment groups was made using the independent 't' test. The comparisons were made at baseline, mid, final and post-final evaluations.

Results of the analysis indicated no significant difference between the two treatment groups at baseline (Table 55); at mid evaluation, only the post-exercise blood lactate values were significantly ($p \angle 0.01$) lower in the Fe treated than the placebo group (Table 56). At final evaluation, both the pre and post-exercise blood lactate values in the Fe treated group were significantly lower than those in the placebo group (Table 57).

Table 58. Comparison of pre and post-exercise pulse rate[a] and blood lactic acid[a] values of the non-anemic, Fe treated versus placebo group subjects at post-final evaluation.

Group	Hb (g/dl)	Pulse rate (beats/min)		Blood lactic acid (mg/dl)	
		Pre-exercise	Post-exercise	Pre-exercise	Post-exercise
Fe treated (16)	11.883 ± 0.171	91.250 ± 2.676	165.50 ± 2.872	-	17.702 ± 1.221
Placebo Group (10)	11.855 ± 0.231	89.00 ± 3.518	164.400 ± 4.214	-	20.999 ± 1.119
't' value	0.0974^{NS}	0.5090^{NS}	0.2157^{NS}	-	1.9908^{NS}

[a]All values are mean $\pm$ SE

NS - Difference between means non-significant.

Non-anemics - Hb $\geqslant$ 11.5 g/dl at baseline.

Table 59. Comparison of pre and post-exercise pulse rate[a] and blood lactic acid[a] values in the anemic versus non-anemic subjects at baseline for the Fe treated and placebo groups.

Group	Hb (g/dl)	Pulse rate (beats/min)		Blood lactic acid (mg/dl)	
		Pre-exercise	Post-exercise	Pre-exercise	Post-exercise
Anemic Fe treated (41)	9.494 ±0.122	97.463 ±1.712	184.537 ±2.312	12.103 ±0.612	29.262 ±1.261
Non-anemic iron treated (16)	12.094 ±0.12	91.625 ±2.80	164.750 ±3.219	10.652 ±0.943	22.516 ±2.593
't' values	15.1515***	1.7787	4.9924***	1.2906	2.3391*
Anemic Placebo group (45)	9.611 ±0.113	98.40 ±1.313	184.80 ±2.332	10.414 ±0.732	26.273 ±1.275
Non-anemic placebo group (10)	12.307 ±0.195	86.80 ±2.829	157.80 ±5.219	11.640 ±1.534	24.110 ±1.618
't' values	11.9133***	3.7831***	4.7228***	0.7212[NS]	1.0496[NS]

[a]All values are mean ± SE

NS - Difference between means non-significant

*** Difference between means significant at $p < 0.001$

The difference between the Fe treated and placebo group at post-final evaluation was non-significant, although, the post-exercise blood lactate values in the Fe treated group were lower than those in the placebo group as indicated in Table 58.

From Tables 47 to 55, it was evident that at baseline no significant difference between the two groups in any of the parameters of PWC was observed in the anemics or the non-anemics.

However, from Table 43 to 46 and Table 51 to 54, it appeared that when the within group comparisons were made, the benefit was greater in the anemics than in the non-anemics. Thus, it became imperative to compare the anemic versus the non-anemic subjects for each of the treatment groups using the independent 't' test. Results of these comparisons are indicated in Tables 59 to 62.

The comparison of data at baseline (Table 59) indicated that in the Fe treated group, the anemics had significantly higher post-exercise blood lactate ($p < 0.05$) and pulse rate ($p < 0.001$) values than the non-anemics. Although, the difference in the pre-exercise blood lactate and pulse rate values between the two categories was non-significant, the values for the anemics was higher than those for the non-anemics.

Table 60. Comparison of pre and post-exercise pulse rate[a] and blood lactic acid[a] values in the anemic versus non-anemic subjects at mid evaluation for the Fe treated and placebo groups.

Groups	Hb (g/dl)	Pulse rate (beats/min)		Blood lactic acid (mg/dl)	
		Pre-exercise	Post-exercise	Pre-exercise	Post-exercise
Anemic Fe treated (41)	11.022 ±0.166	96.146 ±1.488	169.756 ±1.946	10.183 ±0.447	20.455 ±0.672
Non-anemic iron treated (16)	12.762 ±0.161	91.625 ±2.80	166.125 ±2.553	8.821 ±0.462	17.296 ±1.013
't' value	7.503***	1.4526[NS]	1.1312[NS]	2.1172*	2.5974*
Anemic placebo group (45)	9.993 ±0.104	98.667 ±1.229	181.20 ±1.636	12.253 ±0.450	27.459 ±1.026
Non-anemic placebo group (10)	12.317 ±0.147	87.20 ±2.636	163.20 ±4.454	10.480 ±1.089	21.617 ±0.999
't' value	12.8610***	3.9420***	3.7931***	1.5043[NS]	4.0781***

[a]All values are mean ± SE

NS - Difference between means non-significant

*** Difference between means significant at $p \angle 0.001$

Table 61. Comparison of pre and post-exercise pulse rate[a] and blood lactic acid[a] values in the anemic versus non-anemic subjects at final evaluation for the Fe treated and placebo group.

Groups	Hb (g/dl)	Pulse rate (beats/min)		Blood lactic acid (mg/dl)	
		Pre-exercise	Post-exercise	Pre-exercise	Post-exercise
Fe treated anemics (41)	11.958 $\pm$0.119	93.951 $\pm$1.318	174.00 $\pm$1.451	9.485 $\pm$0.302	18.259 $\pm$0.397
Fe treated non-anemics (16)	13.013 $\pm$0.15	90.375 $\pm$2.478	162.375 $\pm$1.855	7.622 $\pm$0.380	13.979 $\pm$0.643
't' values	5.5033***	1.2739^{NS}	4.9354***	3.8325***	5.6319***
Placebo group anemics (45)	10.022 $\pm$0.097	98.133 $\pm$1.064	178.267 $\pm$1.422	11.235 $\pm$0.462	25.554 $\pm$0.930
Placebo group non-anemics (10)	12.194 $\pm$0.191	87.00 $\pm$2.72	160.20 $\pm$4.903	11.760 $\pm$1.103	21.754 $\pm$1.297
't' value	10.0976***	3.8113***	3.5388**	0.4388^{NS}	2.3799*

[a]All values are mean $\pm$ SE

NS - Difference between means non-significant
* Difference between means significant at $p < 0.05$
** Difference between means significant at $p < 0.01$
*** Difference between means significant at $p < 0.001$

Table 62. Comparison of pre and post-exercise pulse rate[a] and blood lactic acid[a] values in the anemic versus non-anemic subjects at post-final evaluation, in the Fe treated and placebo groups.

Groups	Hb (g/dl)	Pulse rate (beats/min)		Blood lactic acid (mg/dl)	
		Pre-exercise	Post-exercise	Pre-exercise	Post-exercise
Anemic Fe treated (41)	10.130 ±0.130	97.415 ±1.576	179.561 ±1.855	-	29.093 ±0.883
Non-anemic Fe treated (16)	11.833 ±0.171	91.250 ±2.676	165.50 ±2.872	-	17.702 ±1.221
't' value	8.1496***	1.9849[NS]	4.1122***	-	7.5552***
Anemic placebo group (45)	9.765 ±0.084	96.444 ±1.261	181.333 ±1.694	-	25.580 ±0.806
Non-anemic placebo group (10)	11.855 ±0.231	89.00 ±3.518	164.400 ±4.214	-	20.999 ±1.119
't' value	8.4959***	1.9915[NS]	3.7280***	-	3.3205**

[a]All values are mean ± SE

NS - Difference between means non-significant
** Difference between means significant at p $\angle$ 0.01
*** Difference between means significant at p $\angle$ 0.001

Similar comparisons between the placebo group anemic and non-anemic subjects indicated that the pre and post-exercise pulse rate values were significantly ($p < 0.001$) higher in the anemics than in the non-anemics; and only a trend was indicated for the post-exercise blood lactate values.

At mid evaluation (Table 60) no statistically significant differences between the Fe treated anemic and non-anemic subjects in the pre and post exercise pulse rates were observed. Differences between the two groups were significant ($p < 0.05$) for the pre and post-exercise blood lactate values.

For the placebo group, significant differences between the anemics and non-anemics for the pre and post-exercise pulse rate ($p < 0.001$) and post-exercise blood lactate ($p < 0.001$) values were observed.

The data at final evaluation (Table 61) still indicated significant differences between the anemic and non-anemic subjects, in the pre and post-exercise blood lactate and post-exercise pulse rate values for the Fe treated group. For the placebo group the situation was largely unchanged from that at mid evaluation.

The differences between the anemic and non-anemic subjects in the Fe treated group were observed at post-final evaluation (Table 62) in the post exercise blood lactate and pulse rate values. The results for the placebo group were similar.

The results of these comparisons did not indicate any significant betterment in the anemics as compared to the non-anemics.

4 Impact of supplementation on younger and older subjects

Most studies conducted on anemia and PWC have been on animals (Glover and Jacobs, 1972; Edgerton et al, 1972). The physiological effects of anemia on PWC have been studied in the animals (Koziol et al, 1982) and in human subjects by Rodman et al, 1960; studies related to work productivity in adults have also been conducted (Basta et al, 1974; Gardner et al, 1975; Edgerton et al, 1981; Rahamathulah, 1984). Numerous studies on children (Bar-Or et al, 1971; Macek and Vavra, 1971; Seshadri and Malhotra, 1982; Gopaldas et al, 1985b) have indicated the beneficial effects of Fe supplementation on PWC. However, no attempts have been made in either study to compare the impact of iron supplementation on various parameters of PWC with age as variable.

Hence, in the present study an attempt was made to examine the effect of iron supplementation on pre and post-exercise blood lactate and pulse rate values (the two measures of PWC observed in this study), after classifying the subjects into 2 age categories.

The age categories were :

1 Younger girls - age $\angle$ 11 years

2 Older girls - age $\geqslant$ 11 years.

Table 63. Changes in pre and post-exercise blood lactic acid[a] values in the younger (age $\angle$ 11 years) Fe treated subjects over one year study period.

N=60	Hb (g/dl)	Blood lactic acid (mg/dl)	
		Pre-exercise	Post-exercise
Baseline (B)	10.467±0.140	11.693±0.5757	27.162±1.2862
Mid (M)	11.690±0.122	9.792±0.3601	19.532±0.5738
Final (F)	12.406±0.095	8.697±0.2694	16.771±0.4332
Post-final (PF)	10.824±0.123	–	24.710±0.8328
Paired 't' values			
B Vs M	11.80***	-3.60***	-6.48***
B Vs F	17.99***	-5.75***	-8.71***
B Vs PF	3.79***	-	1.87[NS]
M Vs F	11.71***	-4.96***	-8.03***
M Vs PF	-7.75***	-	5.94***
F Vs PF	-15.23***	-	10.10***

[a]All values are mean ± SE

NS - Difference between means non-significant

*** Difference between means significant at p $\angle$ 0.001.

Table 64 . Changes in pre and post-exercise blood lactic acid[a] values in the younger (age $\angle$ 11 yrs) placebo group subjects over one year study period.

N=60	Hb (g/dl)	Blood lactic acid (mg/dl)	
		Pre-exercise	Post-exercise
Baseline (B)	10.39±0.130	11.051±0.648	24.392±1.046
Mid (M)	10.64±0.144	12.265±0.421	25.736±0.885
Final (F)	10.62±0.135	11.295±0.409	24.191±0.779
Post-final (PF)	10.35±0.109	-	24.423±0.687
Paired 't' values			
B Vs M	2.72*	2.11*	1.53^{NS}
B Vs F	2.85**	0.54^{NS}	-0.23^{NS}
B Vs PF	-0.71^{NS}	-	0.03^{NS}
M Vs F	-0.54^{NS}	-2.91**	-3.27**
M Vs PF	-3.71***	-	-2.99**
F Vs PF	-3.13**	-	0.66^{NS}

[a]All values are mean ± SE

NS - Difference between means non-significant

* Difference between means significant at p $\angle$ 0.05
** Difference between means significant at p $\angle$ 0.01
*** Difference between means significant at p $\angle$ 0.001

Table 65. Changes in pre and post-exercise pulse rate[a] values in the younger (age $<$ 11 yrs) Fe treated subjects over one year study period.

N=60	Hb (g/dl)	Blood lactic acid (mg/dl)	
		Pre-exercise	Post-exercise
Baseline (B)	10.467±0.140	94.467±1.5058	174.933±2.334
Mid (M)	11.690±0.122	93.733±1.4162	166.700±1.556
Final (F)	12.406±0.095	91.800±1.2619	168.400±1.374
Post-final (PF)	10.824±0.123	94.233±1.4652	172.933±1.906
Paired 't' values			
B Vs M	11.80***	-1.24[NS]	-4.37***
B Vs F	17.99***	-3.40**	-4.54***
B Vs PF	3.79***	-0.63[NS]	-2.17*
M Vs F	11.71***	-4.41***	1.20[NS]
M Vs PF	-7.75***	1.05[NS]	4.07***
F Vs PF	-15.23***	3.49**	4.0***

[a]All values are mean ± SE

NS - Difference between means non-significant

* Difference between means significant at $p < 0.05$
** Difference between means significant at $p < 0.01$
*** Difference between means significant at $p < 0.001$.

Comparisons were made within the groups using the paired 't' test and between the groups using the independent 't' test.

The results of these analysis were as follows :

Younger subjects

1 . Within group comparison

Highly significant decrease in the pre and post-exercise blood lactate values ($p < 0.001$) were observed on iron supplementation at mid and final evaluations in the younger subjects.

At post-final evaluation, there was a significant increase in the blood lactate values from those at mid and at final evaluations. This value however, did not differ significantly from the baseline value, although it was lower (Table 63).

Blood lactate values for the placebo treated younger subjects (Table 64) indicated a significant increase in the pre-exercise and a non-significant increase in the post-exercise blood lactate values at mid evaluation. The values at final evaluation were lower than those at mid evaluation, but the difference was non-significant. No significant change in the post-exercise blood lactate values at post-final, from the values at baseline or at final was observed.

Table 65 illustrates the changes in the pre and post-exercise pulse rate values in the Fe treated younger subjects

Table 66. Changes in the pre and post-exercise pulse rate[a] values in the younger (age $\angle$ 11 yrs) placebo group subjects over one year study period

N=60	Hb (g/dl)	Pulse rate (beats/min)	
		Pre-exercise	Post-exercise
Baseline (B)	10.39±0.130	96.733±1.294	178.80±2.434
Mid (M)	10.64±0.144	97.133±1.205	178.40±1.644
Final (F)	10.62±0.135	96.70± 1.124	176.10±1.542
Post-final (PF)	10.35±0.109	96.533±1.223	178.00±1.715
Paired 't' values			
B Vs M	2.72**	2.05*	-0.24^{NS}
B Vs F	2.85**	-0.03^{NS}	-1.26^{NS}
B Vs PF	-0.71^{NS}	-0.27^{NS}	-0.53^{NS}
M Vs F	-0.54^{NS}	-0.47^{NS}	-1.79^{NS}
M Vs PF	-3.17**	-0.80^{NS}	-0.34^{NS}
F Vs PF	-3.13**	-0.15^{NS}	1.22^{NS}

[a]All values are mean ± SE

NS - Difference between means non-significant

* Difference between means significant at p $\angle$ 0.05

** Difference between means significant at p $\angle$ 0.01

Table 67. Comparison of pre and post-exercise pulse rate[a] and blood lactic acid[a] values in Fe treated versus placebo group younger (age < 11 yrs.) subjects at baseline evaluation

Groups	Hb (g/dl)	Pulse rate (beats/min)		Blood lactic acid (mg/dl)	
		Pre-exercise	Post-exercise	Pre-exercise	Post-exercise
Fe treated younger (60)	10.467 ± 0.140	94.467 ± 1.5058	174.933 ± 2.334	11.693 ± 0.5757	27.162 ± 1.2862
Placebo group younger (60)	10.39 ± 0.130	96.733 ± 1.294	178.80 ± 2.434	11.051 +0.648	24.39 ± 1.046
't' values	0.4031^{NS}	1.1413^{NS}	1.1467^{NS}	0.7407^{NS}	1.6720^{NS}

[a]All values are mean ± SE

NS - Difference between means non-significant.

Table 68. Comparison of pre and post-exercise pulse rate[a] and blood lactic acid[a] values in the Fe treated versus placebo group younger (age $<$ 11 yrs) subjects at mid evaluation.

Groups	Hb (g/dl)	Pulse rate (beats/min)		Blood lactic acid (mg/dl)	
		Pre-exercise	Post-exercise	Pre-exercise	Post-exercise
Younger Fe treated (60)	11.690 $\pm$0.122	93.733 $\pm$1.4162	166.700 $\pm$ 1.556	9.792 $\pm$0.3601	19.532 $\pm$0.5738
Younger placebo group (60)	10.64 $\pm$0.144	97.133 $\pm$1.205	178.40 $\pm$1.644	12.265 $\pm$0.421	25.736 $\pm$0.885
't' values	5.5703***	1.8285[NS]	5.1689***	4.4647***	5.8822***

[a]All values are mean $\pm$ SE

NS - Difference between means non-significant

*** Difference between means significant at $p < 0.001$.

over the one year study period. Results of the paired 't' analysis indicated significant changes at mid ($p < 0.001$), final ($p < 0.001$) and post-final ($p < 0.05$) post-exercise pulse rate values. The values changed from 175 to 166 to 168 to 173 beats/min at baseline, mid, final and post-final evaluations respectively.

Significant decrease in the pre-exercise pulse rate values were observed only at final evaluation in this group.

However, for the placebo treated group, no significant changes were observed in the post-exercise pulse rate values; significant increase was observed in the pre-exercise pulse rate values only at mid evaluation. The changes at final and post-final evaluations were non-significant (Table 66).

2 Between group comparison

The younger subjects in the iron treated and placebo groups did not differ significantly with respect to any of the PWC parameters i.e. pre and post-exercise blood lactate or pulse rate values at baseline (Table 67). Highly significant differences at mid evaluation (Table 68) were observed in the pre and post-exercise blood lactate and post-exercise pulse rate values. The values for each parameter, including the pre-exercise pulse rate (which differed non-significantly) were lower in the Fe treated than in the placebo group.

Table 69. Comparison of pre and post-exercise pulse rate[a] and blood lactic acid[a] values in the Fe treated versus placebo group younger (age < 11 yrs) subjects at final evaluation.

Groups	Hb (g/dl)	Pulse rate (beats/min)		Blood lactic acid (mg/dl)	
		Pre-exercise	Post-exercise	Pre-exercise	Post-exercise
Younger Fe treated (60)	12.406 ±0.095	91.800 ±1.2619	168.400 ±1.374	8.697 ±0.2694	16.771 ±0.4332
Younger Placebo group (60)	10.62 ±0.135	96.70 ±1.124	176.10 ±1.542	11.295 ±0.409	24.191 ±0.779
't' values	10.8242***	2.8995**	3.7282***	5.3063***	8.3249***

[a]All values are mean ± SE

** Difference between means significant at $p < 0.01$

*** Difference between means significant at $p < 0.001$

Table 70. Comparison of pre and post-exercise pulse rate[a] and blood lactic acid[a] values in the Fe treated versus placebo group younger (age $<$ 11 yrs) subjects at post-final evaluation.

Groups	Hb (g/dl)	Pulse rate (beats/min)		Blood lactic acid (mg/dl)	
		Pre-exercise	Post-exercise	Pre-exercise	Post-exercise
Younger Fe treated (60)	10.824 $\pm$0.123	94.233 $\pm$1.4652	172.933 $\pm$ 1.906	-	24.710 $\pm$0.8328
Younger placebo group (60)	10.35 $\pm$0.109	96.533 $\pm$1.223	178.00 $\pm$1.715	-	24.423 $\pm$0.687
't' values	2.8867**	1.2051[NS]	1.9762*	-	0.7925[NS]

[a]All values are mean $\pm$ SE

NS - Difference between means non-significant
* Difference between means significant at $p < 0.05$
** Difference between means significant at $p < 0.01$

Table 71. Changes in pre and post-exercise blood lactic acid[a] values in the older (age $\geq$ 11 yrs) Fe treated subjects over one year study period.

N=23	Hb (g/dl)	Blood lactic acid (mg/dl)	
		Pre-exercise	Post-exercise
Baseline (B)	10.38±0.302	11.629±0.8102	23.096±1.7450
Mid (M)	11.613±0.297	9.730±0.5871	19.508±0.8903
Final (F)	12.318±0.181	8.563±0.3918	16.903±0.5431
Post-final (PF)	10.69±0.235	-	25.906±1.475
Paired 't' values			
B Vs M	6.39***	-2.58*	-2.54*
B Vs F	7.46***	-4.09***	-4.04***
B Vs PF	2.88**	-	1.37[NS]
M Vs F	2.99**	-2.80*	-4.04***
M Vs PF	-5.30***	-	3.82***
F Vs PF	-7.90***	-	6.70***

[a]All values are mean ± SE

NS - Difference between means non-significant

* Difference between means significant at $p < 0.05$

** Difference between means significant at $p < 0.01$

*** Difference between means significant at $p < 0.001$

Table 72. Changes in pre and post exercise blood lactic acid[a] values in the older (age $\geq$ 11 yrs) placebo group subjects over one year study period.

N-23	Hb (g/dl)	Blood lactic acid (mg/dl)	
		Pre-exercise	Post-exercise
Baseline (B)	10.46 ± 0.299	11.541 ± 1.0171	25.562 ± 1.575
Mid (M)	10.92 ± 0.205	11.16 ± 0.655	23.717 ± 1.100
Final (F)	10.94 ± 0.180	12.16 ± 0.613	22.606 ± 0.929
Post-final (PF)	10.51 ± 0.227	-	22.48 ± 0.924
Paired 't' values			
B Vs M	3.13**	-0.36 NS	-1.27 NS
B Vs F	2.66*	0.80 NS	-1.95 NS
B Vs PF	0.42 NS	-	-1.99 NS
M Vs F	0.32 NS	1.95 NS	-3.31**
M Vs PF	-4.16***	-	-2.83**
F Vs PF	-3.68**	-	-0.36 NS

[a] All values are mean ± SE

NS - Difference between means non-significant

* Difference between means significant at $p < 0.05$

** Difference between means significant at $p < 0.01$

*** Difference between means significant at $p < 0.001$.

At final evaluation (Table 69) the values for pre and post-exercise blood lactate and pulse rate were significantly lower in the Fe treated than in the placebo group. The values for the pre and post-exercise pulse rate remained lower in the iron treated group than the placebo at post-final evaluation. The difference was significant ($p < 0.05$) only for the post-exercise pulse rate values. No difference between the two groups for post-exercise blood lactate values was observed (Table 70).

Older subjects

1 Within group comparison

Table 71 indicates a significant decrease in the pre and post-exercise blood lactate values in the Fe treated older subjects at mid ($p < 0.05$) and at final ($p < 0.001$) evaluations. At post-final evaluation, the post-exercise blood lactate values had increased significantly from those at mid and final evaluations. These values were higher than those at baseline although, the difference was non-significant.

Table 72 indicates the changes in the pre and post-exercise blood lactate values for the older subjects in the placebo group. Results of the paired 't' analysis indicated that the changes in the pre and post-exercise blood lactate values did not differ significantly throughout the study. Only a trend for lower post-exercise blood lactate values was observed in this group, on subsequent testing.

Table 73. Changes in pre and post-exercise pulse rates[a] in the older (age $\geq$ 11 yrs) Fe treated subjects over one year study period.

N=23	Hb (g/dl)	Pulse rate (beats/min)	
		Pre-exercise	Post-exercise
Baseline (B)	10.38±0.302	95.217±2.3347	176.087±3.428
Mid (M)	11.613±0.297	94.435±2.0736	169.913±2.513
Final (F)	12.318±0.181	91.826±1.7052	170.087±1.8328
Post-final (PF)	10.69±0.235	94.696±2.0647	172.957±2.3631
Paired 't' values			
B Vs M	6.39***	-1.37 NS	-2.32*
B Vs F	7.46***	-2.19*	-2.32*
B Vs PF	2.88**	-0.81 NS	-1.82 NS
M Vs F	2.99**	-1.86 NS	0.07 NS
M Vs PF	-5.30***	0.57 NS	1.45 NS
F Vs PF	-7.9***	1.97 NS	1.80 NS

[a]All values are mean ± SE

NS - Difference between means non-significant

* Difference between means significant at $p < 0.05$

** Difference between means significant at $p < 0.01$

*** Difference between means significant at $p < 0.001$.

Table 74. Changes in pre and post-exercise pulse rates[a] in the older (age $\geq$ 11 yrs) placebo group subjects over one year study period.

N=23	Hb (g/dl)	Pulse rate (beats/min)	
		Pre-exercise	Post-exercise
Baseline (B)	10.465$\pm$0.299	96.522$\pm$2.0284	179.217$\pm$4.6857
Mid (M)	10.919$\pm$0.205	96.522$\pm$2.1637	173.739$\pm$3.2334
Final (F)	10.94 $\pm$0.180	96.522$\pm$1.9929	172.174$\pm$3.028
Post-final (PF)	10.51$\pm$0.227	95.304$\pm$1.9865	178.696$\pm$3.6563
<u>Paired 't' values</u>			
B Vs M	3.13**	0.0^{NS}	-2.61*
B Vs F	2.66*	0.0^{NS}	-1.87^{NS}
B Vs PF	0.42^{NS}	-1.31^{NS}	-0.29^{NS}
M Vs F	0.32^{NS}	0.0^{NS}	-0.53^{NS}
M Vs PF	-4.16***	-1.43^{NS}	3.22**
F Vs PF	-3.68**	-1.14^{NS}	1.96^{NS}

[a]All values are mean $\pm$ SE .

NS - Difference between means non-significant

* Difference between means significant at $p < 0.05$

** Difference between means significant at $p < 0.01$

*** Difference between means significant at $p < 0.001$.

Table 75. Comparison of pre and post-exercise pulse rate[a] and blood lactic acid[a] values in the Fe treated versus the placebo group older (age ⩾ 11 yrs) subjects at at baseline evaluation.

Groups	Hb (g/dl)	Pulse rate (beats/min)		Blood lactic acid (mg/dl)	
		Pre-exercise	Post-exercise	Pre-exercise	Post-exercise
Older Fe treated (23)	10.38 ±0.302	95.217 ±2.334	176.087 ±3.428	11.629 ±0.810	23.096 ±1.745
Older placebo (23)	10.465 ±0.299	96.522 ±2.028	179.217 ±4.685	11.541 ±1.017	25.562 ±1.575
't' value	0.2000[NS]	0.4220[NS]	0.5391[NS]	0.0676[NS]	1.049[NS]

[a]All values are mean ± SE

NS - Difference between means non-significant.

Results for the pre and post-exercise pulse rate values in the older Fe treated subjects indicated a significant drop ($p < 0.05$) in the post-exercise pulse rate values at mid and final evaluations. The pulse rate values prior to the exercise dropped at subsequent testing but was significantly lower than those at baseline only at final evaluation. A non-significant increase, both in the pre and post-exercise values was observed at post-final evaluation (Table 73).

For the placebo group (Table 74) significant decrease in the post-exercise pulse rate values was observed at mid evaluation. No changes in the pre-exercise pulse rate values were significant at any point of time.

2 Between group comparison

Since older subjects showed benefit on either of the two treatments, in the parameters for PWC, it was necessary to compare the effects of the two treatments in this age group.

Results of the independent 't' test at baseline (Table 75) indicated that the two groups did not differ significantly in any of the measures of PWC studied. Thus, whatever the differences, if any, that would emerge during the course of the study could be attributed to Fe-therapy.

Table 76. Comparison of pre and post-exercise pulse rate[a] and blood lactic acid[a] values in the Fe treated versus placebo group older (age ≥ 11 yrs) subjects at mid evaluation.

Groups	Hb (g/dl)	Pulse rate (beats/min)		Blood lactic acid (mg/dl)	
		Pre exercise	Post-exercise	Pre-exercise	Post-exercise
Older Fe treated (23)	11.613 ±0.297	94.435 ±2.073	169.913 ±2.513	9.730 ±0.587	19.508 ±0.890
Older placebo (23)	10.919 ±0.205	96.522 ±2.1637	173.739 ±3.233	11.16 ±0.655	23.717 ±1.100
't' value	1.9235[NS]	0.6965[NS]	0.9343[NS]	1.6259[NS]	2.9747**

[a]All values are mean ± SE

NS - Difference between means non-significant

** Difference between means significant at $p < 0.01$.

Table 77. Comparison of pre and post-exercise pulse rate[a] and blood lactic acid[a] values in the Fe treated versus placebo group older subjects at final evaluation (age $\geq$ 11 yrs)

Groups	Hb (g/dl)	Pulse rate (beats/min)		Blood lactic acid (mg/dl)	
		Pre-exercise	Post exercise	Pre-exercise	Post exercise
Older Fe treated (23)	12.318 $\pm$0.181	91.826 $\pm$1.705	170.087 $\pm$1.832	8.563 $\pm$0.391	16.903 $\pm$0.543
Older placebo (23)	10.94 $\pm$0.180	96.522 $\pm$1.992	172.174 $\pm$3.028	12.16 $\pm$0.613	22.606 $\pm$0.929
't' values	5.4018***	1.7909[NS]	0.5897[NS]	4.9477***	5.3001***

[a]All values are mean $\pm$ SE

NS - Difference between means non-significant

*** Difference between means significant at $p < 0.001$.

Table 78. Comparison of pre and post exercise pulse rate[a] and post-exercise blood lactic acid[a] values in the Fe treated versus placebo group older (age $\geqslant$ 11 yrs) subjects at post-final evaluation.

Groups	Hb (g/dl)	Pulse rate (beats/min)		Blood lactic acid (mg/dl)	
		Pre-exercise	Post exercise	Pre-exercise	Post-exercise
Older Fe treated (23)	10.69 ±0.235	94.696 ±2.064	172.957 +2.3631	-	25.906 ±1.475
Older Placebo (23)	10.51 ±0.227	95.304 ±1.986	178.696 ±3.556	-	22.48 ±0.924
't' value	0.5511[NS]	0.2122[NS]	1.8592[NS]	-	1.9683[NS]

[a]All values are mean ± SE

NS - Difference between means non-significant.

Table 79. Comparison of pre and post-exercise pulse rate[a] and blood lactic acid[a] values in the younger versus older subjects at baseline evaluation, for the Fe treated and placebo groups.

Groups	Hb (g/dl)	Pulse rate (beats/min)		Blood lactic acid (mg/dl)	
		Pre-exercise	Post-exercise	Pre-exercise	Post-exercise
Younger Fe treated (60)	10.467 ±0.140	94.467 ±1.505	174.933 ±2.334	11.693 ±0.575	27.162 ±1.286
Older Fe treated (23)	10.38 ±0.302	95.217 ±0.334	176.087 ±3.428	11.629 ±0.81	23.096 ±1.745
't' values	0.1786[NS]	0.2699[NS]	0.2782[NS]	0.0643[NS]	1.8756[NS]
Younger placebo (60)	10.39 ±0.130	96.733 ±1.294	178.8 ±2.434	11.051 ±0.648	24.39 ±1.046
Older placebo (23)	10.465 ±0.299	96.522 ±2.028	179.217 ±4.685	11.541 ±1.017	25.562 ±1.575
't' values	0.2293[NS]	0.0683[NS]	0.0789[NS]	0.4062[NS]	0.6188[NS]

[a]All values are mean ± SE

NS - Difference between means non-significant.

At mid evaluation (Table 76) the Fe treated group had significantly lower post-exercise blood lactate values than the placebo group. The values for the pre and post-exercise pulse rate and pre-exercise blood lactate values although lower, were not significantly different in the two treatment groups. At final evaluation (Table 77) both the pre and post-exercise blood lactate values were significantly ($p \angle 0.001$) lower in the Fe treated than in the placebo group. The pulse rate values, although low did not differ significantly.

At post-final evaluation (Table 78) the differences in any of the parameters were non-significant in the two treatment groups.

As indicated from Tables 67 to 70 and Tables 75 to 78 for the younger and older subjects respectively, iron supplementation certainly benefitted the subjects in measures of PWC which were lower in the Fe treated group as against the placebo group.

However, it was necessary to compare the two groups i.e. the younger versus the older for each treatment to establish which of the two groups showed a larger benefit on supplementation as the study progressed.

The analysis of data using the independent 't' test, indicated that the younger and older subjects in the Fe treated and placebo groups were at par with each other at baseline (Table 79).

Table 80. Comparison of pre and post-exercise pulse rate[a] and blood lactic acid[a] values in the younger versus older subjects at mid evaluation, for the Fe treated and placebo groups.

Groups	Hb (g/dl)	Pulse rate (beats/min)		Blood lactic acid (mg/dl)	
		Pre-exercise	Post-exercise	Pre-exercise	Post-exercise
Younger Fe treated (60)	11.690 ±0.122	93.733 ±1.416	166.70 ±1.556	9.792 ±0.36	19.532 ±0.573
Older Fe treated (23)	11.613 ±0.297	94.435 ±2.073	169.913 ± 2.513	9.730 ±0.587	19.508 ±0.890
't' values	0.2395[NS]	0.2795[NS]	1.0869[NS]	0.09[NS]	0.0226[NS]
Younger placebo (60)	10.64 ±0.144	97.133 ±1.205	178.40 ±1.644	12.265 ±0.421	25.736 ±0.885
Older placebo (23)	10.919 ±0.205	96.522 ±2.1637	173.739 ±3.233	11.16 ±0.655	23.717 ±1.100
't' values	1.1075[NS]	0.2467[NS]	1.2849[NS]	1.6067[NS]	1.4299[NS]

[a]All values are mean ± SE

NS - Difference between means non-significant.

Table 81. Comparison of pre and post-exercise pulse rate[a] and blood lactic acid[a] values in the younger versus older subjects at final evaluation, for the Fe treated and placebo groups.

Groups	Hb (g/dl)	Pulse rate (beats/min)		Blood lactic acid (mg/dl)	
		Pre-exercise	Post-exercise	Pre-exercise	Post-exercise
Younger Fe treated (60)	12.406 $\pm$0.095	91.800 $\pm$1.261	168.4 $\pm$1.374	8.697 $\pm$0.269	16.771 $\pm$0.433
Older Fe treated (23)	12.318 $\pm$0.181	91.826 $\pm$1.705	170.087 $\pm$1.832	8.563 $\pm$0.391	16.903 $\pm$0.543
't' values	0.4184[NS]	0.0122[NS]	0.7363[NS]	0.1720[NS]	0.1583[NS]
Younger placebo (60)	10.62 $\pm$0.135	96.70 $\pm$1.124	176.10 $\pm$1.542	11.295 $\pm$0.409	24.191 $\pm$0.779
Older placebo (23)	10.94 $\pm$0.180	96.522 $\pm$1.992	172.174 $\pm$3.028	12.16 $\pm$0.613	22.606 $\pm$0.929
't' values	1.1203[NS]	0.0778[NS]	1.1554[NS]	1.1731[NS]	1.3064[NS]

[a]All values are mean $\pm$ SE

NS - Difference between means non-significant.

Table 82. Comparison of pre and post-exercise pulse rate[a] and blood lactic acid[a] values in the younger versus older subjects at post-final evaluation, for Fe treated and placebo groups.

Groups	Hb (g/dl)	Pulse rate (beats/min)		Blood lactic acid (mg/dl)	
		Pre-exercise	Post-exercise	Pre-exercise	Post-exercise
Younger Fe treated (60)	10.824 ±0.123	94.233 ±1.4652	172.933 ±1.906	-	24.710 ±0.832
Older Fe treated (23)	10.69 ±0.233	94.696 ±2.064	172.957 ±2.3631	-	25.906 ±1.475
't' values	0.5013^{NS}	0.1828^{NS}	7.38×10^{-3} NS	-	0.7060^{NS}
Younger placebo (60)	10.35 ±0.109	96.533 ±1.223	178.00 ±1.715	-	24.423 ±0.687
Older placebo (23)	10.51 ±0.227	95.304 ±1.986	178.696 ±3.656	-	22.48 ±0.924
't' values	0.6364^{NS}	0.5268^{NS}	0.1723^{NS}	-	1.943^{NS}

[a]All values are mean ± SE

NS - Difference between means non-significant.

None of the parameters differed significantly from each other.

Results of the similar analysis at mid, final and post-final evaluations are indicated in Tables 80, 81 and 82 respectively.

The analysis indicated that both the younger and the older subjects benefitted equally from the Fe treatment at mid and final evaluations; the effect of withdrawal of supplementation was similar in the two age categories.

Thus, no difference in the benefit of Fe therapy between the two age categories could be observed in this study.

To sum up the results to fulfill Objective III (i.e. Impact of the Fe supplementation on PWC) indicated that :

(1) Fe supplementation significantly reduced the pre and post exercise BLA and post exercise PR values at each evaluation.

(2) A significant inverse relationship between the pre and post-exercise BLA and PR values, and Hb values was observed.

(3) Subjects who were anemic (Hb $\leq$ 10.5 g/dl) initially, performed poorly in tests of physical work. On Fe supplementation performance improved but continued to be lower that that of the non-anemic (Hb $\geq$ 11.5 g/dl) counterparts.

(4) Both, the younger (age $<$ 11 yrs) and older (age $\geq$ 11 yrs) subjects benefitted equally from Fe supplementation at mid and final evaluations, and the effect of withdrawal of supplementation in the two age groups was similar.

DISCUSSION

Results of the present study are similar to those of Basta et al (1974; 1979), Gardner et al (1975) and many other investigators who demonstrated a significantly lower work tolerance in the anemic than in the non-anemic subjects.

Edgerton et al (1972) studied the capacity of iron deficient rats to run a treadmill in order to avoid an electric shock. As the packed cell volume, Hb, myoglobin and cytochrome C decreased, the running times were also decreased. When Fe was restored to the regimen, the forced running time increased after 3 days and was normal after 7 days, when Hb also returned to normal.

In the present study nearly 90% of the subjects were anemic by the WHO criterion. The subjects showed a significant benefit of Fe supplementation on PWC as measured by the pre and post-exercise blood lactate values and pulse rate values on a fixed work load. The benefit of Fe supplementation was enormous for blood lactate, both pre and post-exercise; but only in post-exercise pulse rate values at mid evaluation. At final evaluation both parameters indicated a significant drop in the values which was in response to the improved PWC. The placebo group showed no changes.

Results of this study showed a significant betterment in the post-exercise blood lactate values on iron supplementation in the non-anemics at mid evaluation, as against the anemics who showed improvements in both the pre and post-exercise blood lactate and pulse rate values. On continued therapy the benefit to the anemics continued and was indicated by significantly lower pre and post-exercise blood lactate and pulse rate values. Whereas in the non-anemics benefit in PWC was observed by virtue of lowered pre and post-exercise blood lactate values. This indicated that although non-anemic subjects, on iron supplementation improve their PWC, the improvement that is observed in the total group is largely due to the anemic subjects.

This has also been reported by Karyadi and Basta (1973) while studying male road construction workers of Java. They observed no difference between subjects classified as anemic and non-anemic taking the cut off point for anemia as Hb $\angle$ 13 g/dl.

Contrary to this finding was that of Basta et al (1979) wherein anemia at a cut off point of 13 g/dl affected Indonesian workers ability to perform work; on Fe supplementation at 100 mg Fe as $FeSO_4$ for 60 days, the Hb status and work output of anemics improved significantly, matching that of the non-anemics.

Edgerton et al (1981) also reported marked reduction in the post-exercise blood lactate values within 24 hours of blood transfusion.

Studies on animals (Koziol et al, 1982), on adults (Astrand, 1958; Gardner et al, 1975; Gardner et al, 1977; Edgerton et al, 1981; Ohira et al, 1981) and on children (Gopaldas et al, 1985), and also results of the present study are in support with the suggestion of Astrand (1956), that, the measure of blood lactic acid is a valuable measure for the degree of exhaustion and thus must be used to measure PWC.

The post-exercise blood lactate and pulse rate values appeared to be sensitive measures of PWC, however, the post-exercise blood lactate measurement exhibited its superiority in sensitivity over the pulse rate values in the present study.

Cifuentes and Viteri (1972) demonstrated plateauing of the benefit of iron supplementation at 120 mg/day after 60 days of therapy on HST scores; the present study indicated a continued benefit even after 60 days of therapy at a dosage that was half the amount given by Cifuentes and Viteri. No attempt was made to study the iron status of the subjects by these investigators whereas, in the present study an attempt to correlate the Hb, SI, TIBC and TS values, at final evaluation, with the various measures of PWC was made.

The Hb, SI, TIBC, TS values highly correlated with the pre and post-exercise blood lactate and post-exercise pulse rate values. These results were in concordance with those of the Gardner et al (1977) who reported a highly significant inverse relationship between Hb status and post-exercise blood lactate values. A significant inverse relationship between SI and post-exercise blood lactate has also been reported by Ohira et al (1981). However, Ericsson (1970) could observe only a weak correlation between the measures of PWC and Hb status in elderly subjects (58-71 years of age). The study implicated that at higher ages the modes of adaptation to anemia to increase PWC may differ. However, no difference between the younger (age $<$ 11 years) and older (age $\geq$ 11 years) subjects could be observed in the present study at any point of time indicating that the benefit of Fe therapy was equivalent for both age categories. It must be mentioned here, that Ericsson's subjects were 58-71 years old apparently healthy men and women. Thus, the age category in the present study was probably much smaller to elucidate any difference between the two age categories in the various measures of PWC studied.

However, it would be difficult to compare subjects from two varied age categories due to the importance of matching subjects for various criteria as done in the present study. Macek and Vavra (1971) reported a direct relationship between blood lactate and body weight in 6-14 years old girl subjects, in response to a work load of riding the bicycle ergometer.

The metabolic effects of Fe deficiency within the skeletal muscle are complex, oxidative phosphorylation is decreased along the pyruvate, malate, succinate and α glycerophosphate oxidase pathways (Finch et al, 1976). It was reported that when iron deficient rats Hb was corrected by whole blood transfusion, work capacity was not improved. It was proposed that the critical feature was a decrease in the mitochondrial enzyme system, α glycerophosphate oxidase. Evidence was circumstantial in that the concentration of the enzyme in muscle parallelled changes in work performance.

This is supported by the study by Elwood (1969) who evidenced no beneficial effect on cardiorespiratory function on iron therapy, although Fe therapy had a very marked effect on circulating and total body Hb. Edgerton et al (1972) also reported that normalization of work capacity in anemic animals occurred before the normalization of Hb in response to oral Fe treatment. However, Ohira et al (1978) reported that the mean heart rates in the iron dextran treated subjects during light and moderate exercise were more than 35% lower ($p < 0.05$) than the transfused subjects even though both groups had similar Hb levels. The heart rate responses at each work load of a treadmill exercise for adult human subjects in the transfused subjects were similar to the untreated control subjects who had the same Hb levels.

The rate of phosphorylation with α glycerophosphate in the skeletal muscle is a factor related to improvement in work performance that is unrelated to Hb. However, how this could affect the cardiovascular response, is not clear as yet (Finch et al, 1976).

Ohira et al (1981) reported a significant correlation between SI and the post-exercise blood lactate levels ($r = -0.41$, $p < 0.05$) suggesting that lower the SI, higher the blood lactate after exercise.

The results of the present study also indicated a significant correlation between the SI, TIBC and TS values and the post-exercise blood lactate and pulse rate values. However, the Hb values also correlated at each point of time with their respective post-exercise blood lactate values and at baseline with the resting pulse rate values. Also, the benefit of Fe supplementation on PWC was not sustained as evident from the increase in both pre and post-exercise blood lactate and pulse rate values from those at final evaluation.

As indicated in the Review of Literature most studies pertaining to anemia/impact of Fe supplementation an PWC have either been on animals or on adults with respect to their productivity. There are very few studies conducted on school children. Gopaldas et al (1985 b) studied underprivileged school boys (8-15 years of age) after carefully matching the subjects for age, initial Hb and body size and dividing them into three treatment groups, receiving a placebo, 30 mg or 40 mg elemental Fe as $FeSO_4$ respectively. The results of this study indicated a greater benefit of the 40 mg over 30 mg elemental Fe as $FeSO_4$ for 60 days, evident from a benefit in the work capacity parameters (pre and post-exercise, blood lactate and pulse rate values) in the non-anemic (Hb $\geqslant$ 11.5 g/dl) subjects. However, when the anemic and non-anemic subjects were compared, both the dosages were inadequate in reducing the blood lactate and pulse rate values of the anemic (Hb $\leq$ 10.5 g/dl) subjects so as to be comparable to those of the non-anemics.

This was also observed in the present study wherein a dose of 60 mg elemental Fe as $FeSO_4$ for 60 days each, in each school term over one academic year was insufficient to reduce the blood lactate and pulse rate values of the anemic girl subjects to those of the non-anemic girl subjects of the same age group.

Thus to conclude, a significant betterment in work capacity on Fe therapy was observed in the study population. The measures of PWC were blood lactate and pulse rate at rest and in response to an exercise task. Although, both anemics and non-anemics benefitted from Fe supplementation the values for the anemics differed significantly from those of the non-anemics even on completion of the therapy. A significant correlation was observed between measures of Fe status and PWC.

On withdrawal of Fe therapy a drop in PWC, indicated by increased blood lactate and pulse rate values was observed. Thus, in order to obtain a substantial continued benefit in PWC, the need for long term oral iron therapy is indicated. The data suggests the desirability of correcting anemia in order to maintain health which has economic implications with respect to productivity and efficiency.

IV. Impact of Fe supplementation on growth

The growth parameters measured in this study were height-for-age and weight-for-age.

The height and weight measurements were made at baseline and at final evaluations for all 166 subjects in the two treatment groups.

Comparisons were made both within and between the two treatment groups for height and weight respectively.

Table 83. Impact of supplementation on height for age in underprivileged school girls, 8 - 15 yrs. of age.

Group	Height at baseline (cms)	Height at final (cms)	Paired 't' value
Fe treated group	125.736 ±0.880	133.59 ±0.925	25.81***
Placebo group	125.948 ±0.904	132.137 ±0.911	21.61***
Independent 't' value	0.168 NS	1.12 NS	

All values are mean ± SE

*** Difference between the two significant at p ∠ 0.001.

NS - Difference between means non-significant.

Table 84. Impact of supplementation on weight for age in underprivileged school girls, 8 - 15 yrs of age

Groups	Weight at baseline (kg)	Weight at final (kg)	Paired 't' value
Fe treated group	21.771 ±0.453	24.084 ±0.559	12.91***
Placebo group	21.560 ±0.487	23.934 ±0.597	11.50***
Independent 't' value	0.3171 NS	0.1832 NS	

All values are mean ± SE.

*** Difference between the means significant at $p < 0.001$.

NS Difference between means non-significant.

1. Changes in height and weight on intervention

1. Within group comparison

Height for age

Results of the paired 't' analysis on the baseline and final data revealed a highly significant ($p \angle 0.001$) increase in height in both the treatment groups (Fe and placebo), as indicated in Table 83, horizontally.

Weight for age

A similar paired 't' analysis (Table 84, horizontally) on baseline and final weights of the subjects showed a highly significant ($p \angle 0.001$) increase in the weights in both the treatment groups (Fe and placebo groups).

2. Between group comparison

Height for age

Neither at baseline nor at final evaluation, any difference between the two treatment groups was evident, using the independent 't' test analysis (Table 83, vertically).

Weight for age

In order to make a comparison between the two groups for weight at baseline and at final evaluation, the independent 't' test was employed.

The results (Table 84, vertically) of this analysis demonstrated no significant difference in the mean height of the two treatment groups at baseline or at final evaluation.

A similar comparison made for the mean weight of the subjects in the two treatment groups showed no significant difference at baseline or at final evaluation.

However, an interesting relationship emerged when a comparison between Fe treated and placebo groups was made for the mean increments in height and weight from their respective baseline values (Table 85). The results of the independent 't' test indicated that the Fe treated group showed significantly higher increment in height than the placebo group; the difference in weight increments between the Fe treated and placebo groups were non-significant.

This significant mean increment in height of subjects in the Fe treated group compared to the placebo needs to be viewed with caution and should be further investigated.

Table 85. Mean increments in weight and height in subjects after intervention period of one school year.

Treatment Groups	N	Mean increments (Mean ± SE)	
		Weight (Kg)	Height (Cm)
Fe treated	83	2.31 ± 0.179	7.86 ± 0.304
Placebo	83	2.37 ± 0.206	6.19 ± 0.286
't' value		0.219^{NS}	4.019***

*** Difference between the means significant at $p < 0.001$.
NS Difference between the means non-significant.

Table 86. Comparison between anemic and non-anemic subjects for height and weight in the Fe treated and placebo groups.

Parameter	Iron treated group			Placebo group		
	Anemic subjects	Non-anemics	Independent 't' value	Anemics	Non-anemics	Independent 't' value
Height (cm) baseline	126.1 ±1.276	125.95 ±1.722	0.069	125.85 ±1.130	126.29 ±2.719	0.149
Height (cm) final	133.27 ±1.424	135.01 ±2.007	0.708	132.329 ±1.144	133.07 ±2.703	0.252
Weight (kg) baseline	22.42 ±0.677	21.81 ±1.042	0.493	21.456 ±0.626	22.05 ±1.750	0.319
Weight (kg) final	24.695 ±0.806	24.313 ±1.483	0.226	23.90 ±0.813	24.45 ±1.87	0.269

All values are mean ± SE.

Effect of anemia on growth and growth changes on Fe therapy

As indicated earlier, the subjects were classified as anemics ($Hb \leqslant 10.5$ g/dl) and non-anemics ($Hb \geqslant 11.5$ g/dl) based on their initial Hb levels.

Comparisons were made for the two treatment groups between the anemic and non-anemic subjects (Table 86).

Results of the independent 't' test indicated that the anemics did not differ significantly from the non-anemics in their mean heights or mean weights at baseline or at final evaluation in either Fe treated or placebo groups.

This was further substantiated by a very poor correlation coefficient (r) between the baseline Hb and height ($r = -0.0315$, $p \angle 0.385$), final Hb and height ($r = -0.0719$, $p \angle 0.259$), baseline Hb and weight ($r = -0.1041$, $p \angle 0.174$) and final Hb and weight ($r = -0.1127$, $p \angle 0.155$).

To sum up, the results to fulfill Objective IV (i.e. impact of Fe supplementation on growth) revealed that :

(1) No significant difference between the Fe treated and placebo groups for mean height or mean weight was observed at baseline or final evaluations.

(2) On comparing the mean increments in height or weight from baseline, the Fe treated group showed significantly higher increment in height than the placebo group.

(3) No significant difference in mean height or weight was observed between anemics and non-anemics at baseline or final evaluations, in either Fe treated or placebo groups.

DISCUSSION

The relationship between anemia and growth is still inconclusive. This is evident from the contradictory results obtained by various investigators who suggest a relationship (Garn and Smith, 1973; Mahloudji et al, 1975; Rao et al, 1980) and a lack of relationship (Margo, 1977; Tarvady, 1982) between Hb status and measures of growth, namely height for age and weight for age.

However, studies conducted on animals indicate that growth retardation may be evident only in case of severe anemia. Depression of growth is a late consequence of nutritional iron deficiency (Dallman, 1969). In the young rat, iron lack has no discernible effect on growth until the Hb concentration has stabilized at one quarter to one-third of the normal value; at the same time, myoglobin and cytochrome C reach a plateau at about half the control concentration. After this, the gradual cessation of growth helps to maintain concentrations that allow survival, perhaps by preventing excessive dilution of these Fe compounds within a larger body mass.

An analogous depression of growth in man might be anticipated during the peak incidence of iron deficiency between 6 months to 3 years of age, an interval during which the body weight normally more than doubles (Dallman, 1974).

The results of the present study are in accordance with those of Tarvady (1982) who observed a similar improvement the weight of the subjects treated with iron or placebo tablets. Although, Bhatia (1984) reported a greater benefit in weight gain in the Fe treated over and above that observed in the placebo group, iron therapy was advocated for 6 months as against 45 days by Tarvady (1982) at a dose of 40 mg elemental Fe as $FeSO_4$/day in preschool children. However, the increment in height of the Fe treated subjects was significantly greater than that of the placebo group in the present study.

The lack of a clear-cut effect of iron therapy on growth in the present study may be attributed to :

1 Nearly 60% of the subjects manifested mild to moderate anemia. Hb ranging from 9.0 to 10.11 g/dl.

2 The age group of the study population was 8-15 years as compared to the 3 year olds in Judisch's study and 3-5 yr old preschoolers in Bhatia's study.

3 Bhatia administered 40 mg Fe as $FeSO_4$ for 6 months to 3-5 year old subjects as against 60 mg Fe as $FeSO_4$ for 4 months to 8-15 year old girls in the present study.

Thus, anemia at a level observed had no discernible affect on growth. Also, since the study population was 8-15 year old girls, a period of 8 months with 4 months of Fe supplementation may not be enough to elucidate any benefit of Fe therapy as growth at this age is not as rapid as that in the infant or the preschoolers (i.e. 'the under-fives'). Also, the greater increment in height observed in the Fe treated group than the placebo needs to be looked at with caution and much more work has to be done with a larger sample and for a longer period of time to be able to substantiate this interesting finding.