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In a study to learn whether or not poor nutrition, as indicated by low hemoglobin levels, affects intelligence and behavior, 113 Head Start children in Missoula, Montana took part. Group testing with the Lorge Thorndike Intelligence Test and individual testing with the Wechsler and Primary Scale of Intelligence or Wechsler Intelligence Scale for Children provided IQ information. An experimental group of the Head Start children was given iron tablets daily at school, and a control group was given placebos. Blood tests were taken at intervals in the school year, and teachers rated the behavior of all the children. Results of data analysis indicated that the iron pills did not significantly affect homeglobin levels. However, for those with low hemoglobin levels, increases in the levels were associated with increases in intelligence scores. "A Study of Food and Poverty" (PS 001 721), by the same author, is a longer report on the same subject. (MS)

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THE RELATIONSHIP BETWEEN HEMOGLOBIN LEVEL AND INTELLECTUAL FUNCTION

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Malnutrition, defined by diets that provide less than the recommended allowances, is common among low income people. Does this handicap the performance of the disadvantaged? This study addresses itself to one aspect of that problem, using hemoglobin levels as an index of nutritional status and IQs and behavior ratings as indices of performance among 113 children in Head Start in Missoula, Montana.

The relationships between changes in behavior and changes in IQs and hemoglobin levels are still being analyzed. These will be reported when completed.

PURPOSE

The purposes are to test the hypotheses that

A) Iron supplements to Head Start lunches raise low hemoglobin levels and prevent decreases in high hemoglobin levels.

B) That low hemoglobin levels are associated with low performance on intelligence tests and low teachers' ratings of behavior.

C) That changes in hemoglobin levels are associated with changes in intelligence test performance.

D) That continuing high hemoglobin levels are associated with changes in intelligence test performance.

BACKGROUND

A Preliminary Study of Missoula Children, 1966-67.

Low hemoglobin levels cause apathy, fatigue and irritability, which could influence a child's performance on a group intelligence test.

Hemoglobin levels and scores on Lorge Thorndike Intelligence Tests were available as part of Head Start routine in 1966-67. Blood tests had been conducted in various private physicians' laboratories, with some reported as hematocrit, and some as hemoglobin levels. Hematocrits were divided by 3 to use comparably with hemoglobin levels.

There appeared to be a relationship between hemoglobin level and IQ. Of the 56 scores, all except one IQ over 100 were associated with a hemoglobin level over 12.3 gms o/o. All (except the same one) hemoglobin levels that were 12.0 gms o/o or below were associated with IQs of 95 or below. The one exception was not promoted to first grade, but repeated Head Start because he was "immature"

(his teacher's description; she could not define her reason more specifically.)

Of the 16 children with the highest hemoglobin levels, one was not promoted. Of the 16 children with the lowest hemoglobins, 10 were not promoted to the first grade.

Of those children with IQs under 100, those with hemoglobin levels 10-12 gms % gained 7 points IQ during the Head Start year. Those who began with hemoglobin levels over 12.7 gms % gained 17 points IQ. Those who began with high IQs and high hemoglobins gained 5 points IQ.

The child who had the lowest hemoglobin and the lowest IQ did not appear to be tired and apathetic. He was so disruptive it took the full time of the teacher or her aide to control him so that other children in the classroom could learn. Several other children with low hemoglobin levels had similar though less extreme behavior. Their teacher described them as tired in the way that a child is tired who should have gone to bed several hours ago: active in doing what he wants to do but uncooperative, unreasonable and emotionally unstable when frustrated.

In May, at the end of the Head Start year, the Missoula City-County Health Department repeated tests for hemoglobin levels for 40 of these children. Those that had had fall hemoglobin levels below 12.0 gms % in May had increased levels by 0.4 gms %. Those who had high levels in the fall had decreased levels by 0.8 gms %. That indicated that Head Start foods had neither promoted the production of optimum hemoglobin levels nor prevented decreases. Then in a controlled study, it might be expected that children receiving routine Head Start foods could be used as a control group.

School lunches were purchased from the high school, and consisted of standard Type A School Lunches. Fresh hot rolls were furnished daily made of surplus flour. Meals frequently consisted of casseroles, pizza, and stew. While high school youth who ate large servings received two ounces of meat (part of it included as the eggs cooked in cake, etc.), Head Start children who ate smaller servings ate about one ounce of meat, more or less depending on their appetites. Snacks included daily orange juice and graham crackers or whole wheat bread, and either a protein food or a fruit or vegetable. The protein foods included cheese, hard cooked eggs, cold meat, sunflower seeds, etc. The fruits and vegetables were those that could be eaten as finger foods.

The 1966-67 data stimulated a proposal for this study. A grant was applied for, and a contract received by the University of Montana Foundation from Head Start Research, Office of Economic Opportunity.

Hypoxic Effects on Excitability

Since hemoglobin transports oxygen, probably beyond some point low level of hemoglobin must have hypoxic effects. In hypoxia there is first a lowering of the threshold of excitability and then a progressive failure of irritability (1). That would make the measurement of effects of low hemoglobin levels on activity difficult to measure, particularly in the low-normal levels found among the Missoula children.

<u>Relationship Between Hypohemoglobinemic Hypoxia and High Altitude Hypoxia</u>

The effects of hypoxia due to lowered hemoglobin levels on cortical function are similar to effects of hypoxia due to high altitudes. Regardless of the dynamics of its development, or even the tissue affected, it is probable that the mechanism of the disruptive action of anoxia is the same in all forms not involving poisoning of tissue enzymes (2). Because 97 o/o of the oxygen transported by the blood is carried by hemoglobin, a decrease in hemoglobin concentration has the same effect on interstitial fluid PO_2 as does a decrease in blood flow. Thus, reducing the hemoglobin concentration to one quarter below normal will reduce the interstitial fluid PO_2 to a value of about 13 Hg. (3).

Pertinent studies are cited in the <u>Handbook of Physiology</u> (4):

> Reduction in cerebral oxygen concentration has been reported in various chronic anemias and in pernicious anemia... Successful treatment of the pernicious anemia only partially restored the normal metabolic rate, evidence either of an irreversible effect of a prolonged oxygen deficiency in the brain or of some intracellular effect of the disease quite independent of the anemia. Changes in mental function closely paralleled the changes in cerebral oxygen consumption. It must be pointed out, however, that the reduction in cerebral oxygen consumption observed in the anemias may be the result of a methodolcgical error in the application of the nitrous oxide technique.

In malnutrition, the cardiac output does not compensate for anemia: Bradycardia is one of the more constant findings in severe malnutrition and was notable in studies in Europe during and after the two World Wars. In the Minnesota experiment, the cardiac output for the 32 men was reduced to 55 o/o of the control value at the end of semistarvation (5). At this time their average hemoglobin levels were 11.7 + .8 gm. (6) These levels are similar to those of the low hemoglobin group of the Missoula Head Start children.

Below arterial oxygen saturation of 90 %, deterioration of cerebral functions may be expected. and the manifestations of these deteriorations may readily be predicted. Cortical involvement can lead to sleepiness and lassitude, to a sense of comfort, well-being and satisfaction, perhaps associated with outbursts of hilarity or quarrelsomeness; judgement is impaired and a fixity of purpose frequently seen; pain perception is obtunded early. Visual acuity diminishes early. (7)

The individual rapidly developing anoxia cannot be counted on to recognize the fact, nature or degree of his difficulty. As anoxia develops, the progressive depression of the central nervous system functions affect the powers of introspection, discrimination, logic and judgement. Dizziness and euphoria may be recognized, but these symptoms are not specific for anoxia. With increase in the severity of the anoxia, sensory disturbances develop and include diminished visual and auditory acuity and decreased sensitivity of touch and position sense. Still later, muscular weakness with lack of coordination becomes prominent, and ultimately unconsciousness occurs. Ordinarily this sequence of smoothly developing abnormalities will be completely unrecognized by the victim if it occurs over a few minutes or less and does not involve respiratory obstruction or accumulation of carbon dioxide; since no distressful sensations are produced, the entire experience is comfortable and rather pleasant. Recognition of anoxia may be possible when decreased oxygenation develops slowly. However, by the time anoxia is recognized the individual may lack the ability to help himself. (8)

DURATION OF HYPOXIA

The duration of hypoxia is a factor in its effect:

Twenty percent carboxyhemoglobin represented an anoxia too mild to elicit any acute symptoms in dogs. After about three months of daily exposure to maintain 20% carboxyhemoglobin, dogs showed signs of degenerative changes in the cortex and basal ganglia of the brain, which was confirmed by postmortem examination. There were lesions similar to those produced by acute anoxia. (9)

PROCEDURE

To test the hypothesis that iron supplements to Head Start meals would change hemoglobin levels, an experimental group were given iron tablets daily at school, and a control group were given placebos.

To test the hypothesis that hemoglobin levels are associated with performance on intelligence tests, and with behavior in school, blood tests were made, intelligence tests given, and teachers rated the behavior of all children.

To test the hypotheses that changes in IQ and behavior ratings are associated with a) changes in hemoglobin levels and/or b) continuation of high hemoglobin levels, some children were tested in October, in February and in May. Changes in IQ and behavior during the period when hemoglobin levels were rising (Oct.-Feb.) could be compared with changes in IQ and behavior ratings during a period characterized by continuing high hemoglobin levels (Feb.-May).

However, giving children WPPSI tests three times in eight months might have a practice effect. Therefore it was decided to test half the children three times (Oct., Feb. and May) and the other half two times (Oct. and May). Since the treatment of the two groups would be identical except for the frequency of testing, a difference in the changes of scores between the two groups would indicate a practice effect on WPPSI scores.

Since the purpose of the repeated hemoglobin tests was to study their relationship to IQ, hemoglobin levels (and teachers' ratings) were determined only when children were given WPPSI tests.

Other procedures were identical for all children. All children participated in classroom activities and received Head Start lunches and snacks. Socio-economic data were gathered and a home diet survey was made for all children; these are reported in "A Study of Food and Poverty," attached.

OUTLINE OF PROCEDURE:

All 113 Head Start children:

Participated in classroom activities (with varying responsiveness)

Received Head Start lunches and snacks (ate varying amounts)

Were given Lorge Thorndike Intelligence Tests in October (Form A) and in May (Form B). Serum iron levels and total iron binding capacities were determined for eight children with low Oct. hemoglobin levels and for 6 with high levels.

Group I - Experimental		Group II - Control	
Received 60 mg ferrous sulfate at school daily		Received placebo at school daily	
Group IA	Group IB	Group IIA	Group IIB
3 testing periods Blood tests WPPSI Teacher Ratings	2 testing periods Blood tests WPPSI Teacher Ratings	3 testing periods Blood tests WPPSI Teacher Ratings	2 testing periods Blood tests WPPSI Teacher Ratings

PERMISSION

In September, 1967 in the three weeks before Head Start began, 120 mothers were individually interviewed. The Food Study was explained, and permission asked for their children's participation, including written permission for blood tests. I asked for their help in planning Head Start foods, since they as mothers knew what their children needed better than I. I explained to mothers that from the Food Study we hoped to learn from the mothers what foods the children had at home and what they should be given at school, and from the blood tests how strong the blood was and if that made a difference in how well the children did at school. We hoped with food and with some of the pills to make the blood stronger to find out if that made a difference. Then we, the mothers and I, could better plan the children's foods. All but one mother gave permission. Permission forms are in the appendix.

The study was repeatedly explained in personal visits to mothers who had questions about their children being used as guinea pigs, about the pills and about the repeated blood tests.

BLOOD TESTS

All the children were taken in groups of three and four to the Missoula City-County Health Department for finger pricks for hemoglobin and hematocrit determinations. Children were given their choice of toy (ring, whistle, balloon, etc.) after each test; the trip was made as pleasant as possible.

Hemoglobin levels were determined with HYCCL Cyanmethemoglobin reagent and standard and a Bausch and Lomb Spectrionic "20." 28 samples of Hyland hemoglobin control were analyzed at the same time the children's blood was analyzed. The standard deviation of the control was .19 gms %. These procedures were supervised by Dr. Kenneth Lampert, Health Officer.

Serum iron levels and total iron binding capacities were determined for eight children with low hemoglobin levels and six children with high levels.

INTELLIGENCE TESTS

Twelve graduate students (doctoral candidates in psychology) who had had courses in giving individual intelligence tests gave to all children in October and May, and to half the children in February, individual Wechsler and Primary Scale of Intelligence (to the five year olds) and Wechsler Intelligence Scale for Children (to the six year olds). This testing was supervised by

Dr. H. A. Walters and Mrs. Dorothy Stoner, psychologists.

Teachers gave Lorge Thorndike Intelligence Tests (Forms A and B) to all children in groups of 5 to 8 in October and May. This was a measure of the children's ability to perform in groups.

BEHAVIOR RATINGS

Teachers rated each child on a scale from 1 - 7 in classroom and playground activity, general and fine motor coordination, quickness of reaction to authority, ability to understand directions, attention span, independence in the classroom and on the playground, perseveration, distractibility, self-expression and hyperactivity. The rating sheets are in the appendix. These rating sheets were developed for this study by Dr. H. A. Walters and Mrs. Dorothy Stoner.

IRON SUPPLEMENTS

One half of the children were given iron, the other half as control group were given placebos. To ensure a double blind study, the results of the blood tests were sent from the Health Department to Dr. Howard Reinhardt, the statistician, who ranked the children according to hemoglobin level and assigned a number to each child. A graduate student in mathematics assigned treatment, iron or placebo, randomly in the high, medium and low hemoglobin levels. He attached numbers to the appropriate bottles of pills. The statistician then added the appropriate name to each bottle. Thus no-one knew any particular child's treatment. When a child spilled his pills, or poured orange juice into his bottle, the procedure had to be repeated.

Feosol (60 mg ferrous sulfate) and placebos were made and donated by Smith, Kline and French.

When all fall tests were completed, each child was given one tablet, Feosol or placebo, each day for 108 school days. One pediatrician had protested the giving of tablets to all children, saying Feosol was irritating. Calculations according to the procedure outlined by Moore (9) indicated that 22 mg iron was all that could be utilized with hemoglobin levels of 10.0 - 12.0 grams %. Thus 1 tablet (60 mg iron, 0.2 gm dried ferrous sulfate) was considered to be a dose which gave the children what they could utilize and not give excessive amounts. It was expected that by giving Feosol also to children with high hemoglobin levels, the drop in hemoglobin of 0.8 gms % that had been measured the previous year might be prevented.

PULSE

In May, teachers and aides took childrens' pulse rates, twice each. Pulse rates were averaged for groups of children with high and low hemoglobin levels.

RESULTS:

BLOOD TESTS

Table I gives the percent of children with various hemoglobin levels, and Table II gives hematocrit levels for October, February and May. 12.5 gms % is the national average for five year olds. Approximately half the head start children were below the national average.

TABLE I

% OF CHILDREN WITH VARIOUS HEMOGLOBIN LEVELS

	Hemoglobin Levels 10.0 - 12.0 gms %	12.1 - 12.5 gms %	12.6 - 12.9 gms %	13.0-15.0 gms %
October, n = 112	29 %	20 %	23 %	28 %
February, n = 56	16 %	25 %	34 %	25 %
May, n = 92	21 %	21 %	32 %	26 %

TABLE II

% OF CHILDREN WITH VARIOUS HEMATOCRIT LEVELS

	Hematocrit Levels 36 and below	37	38	39-44
October, n = 112	28 %	21 %	13 %	38 %
February, n = 56	21 %	18 %	32 %	29 %
May, n = 92	20 %	18 %	18 %	44 %

For the 8 low hemoglobin children, the serum iron levels were 20, 30, 50, 50, 59, 69, 99, 99. Of the 6 high hemoglobin levels, 2 were 59, the other 4 were normal. The low hemoglobin children average serum iron level was 60 µg/100 ml (the range in iron deficiency is 7-60 µg/100 ml). (10) The high hemoglobin children average was 89 µg/100 ml. There was no significant difference between these two groups.

The total iron binding capacity of the low hemoglobin children average 370 µg/100 mg (range 361 - 440); for the high hemoglobin children the average was 386 (range 360 - 412). The range in iron deficiency is 450-500 µg/100 ml (11).

For these 4 low hemoglobin children who received iron, serum iron levels decreased 5 µg/100 ml, TIBC decreased 1 µg/100 ml.

For those who received placebo, serum iron levels decreased 2 μg/100 ml, TIBC increased 7 μg/100 ml.

There was not significant difference in hemoglobin levels between those who received iron tablets and those who received placebos. Average changes in hemoglobin levels in three fall hemoglobin ranges given iron or given placebo are given in Table III.

TABLE III

AVERAGE CHANGES IN HEMOGLOBIN LEVELS IN CHILDREN GIVEN PLACEBO OR IRON IN VARIOUS FALL HEMOGLOBIN RANGES

Fall Hemoglobin Level	Average Changes in Hemoglobin Levels With Iron	With Placebo
10.0-12.0 gms %	+0.6	+0.4
12.1-12.5 gms %	+0.3	-0.1
12.6 gms % and over	-0.2	0

Since iron did not change hemoglobin levels as predicted, the February test results are not reported here.

HEMOGLOBIN LEVELS AND INTELLIGENCE TESTS

There was no statistically significant correlation between hemoglobin levels and intelligence test scores. Averages of fall and spring WPPSI (and WISC) and Lorge Thorndike Test scores in various fall hemoglobin ranges are given in Table IV. Spring IQs and spring hemoglobin ranges are given in Table V.

TABLE IV

AVERAGE IQs AND CHANGES IN IQ FOR

CHILDREN IN VARIOUS FALL HEMOGLOBIN RANGES

Fall Hemoglobin Level	Ave. Hb change	Ave. Fall WPPSI	Ave. Spring WPPSI	Ave. Change WPPSI	Ave. Fall LT	Ave. Spring LT	Ave. Change LT
10.0-12.1 gms %	+0.4	94	103	6.5	95	100	7.4
12.1-12.5 gms %	+0.3	90	99	8.9	87	91	2.6
12.6-12.9 gms %	+0.3	95	103	7.6	92	100	8.9
13.0 gms % and over	-0.2	98	104	7.2	91	98	10.9

TABLE V

AVERAGE SPRING IQs FOR CHILDREN

IN VARIOUS SPRING HEMOGLOBIN RANGES

Spring Hemoglobin Level	Ave. Spring WPPSI	Ave. Spring Lorge Thorndike
10.0-12.0 gms %	100	94
12.1-12.5 gms %	105	100
12.6-12.9 gms %	101	98
13.0 gms % and over	104	99

Of the children who began the year with hemoglobin levels below 12.0 gms %, those whose hemoglobins changed by -1.6 to +0.1 gms % (stayed below 12.0 gms %) gained 2.0 points IQ; those whose hemoglobins gained 0.2 - 0.8 gms % gained 3.5 points, and those with hemoglobin gained from .9 to 1.9 gms % gained 14.7 points on the WPPSI. These three groups gained 3.1, 4.8 and 20.3 Lorge Thorndike points. Those data are presented in Table VI. For this group there is a correlation of .74 between changes in hemoglobin and changes in IQ. This was statistically significant.

TABLE VI

AVERAGE CHANGES IN INTELLIGENCE TEST SCORES AMONG CHILDREN WITH FALL HEMOGLOBINS 10.0 - 12.0 GMS %
RANKED BY CHANGE IN HEMOGLOBIN LEVEL

Change Hemoglobin	Change in WPPSI Average	Range	n	Change in Lorge Thorndike Average	Range	n
-1.6 +0.1 gms %	2.0	-9 +12	8	3.1	-12 +19	7
0.2 +0.8 gms %	4.3	-9 +12	11	4.8	-12 +10	10
0.9 +1.9 gms %	14.7	+6 +29	7	20.3	+16 +28	4

Of the children with fall hemoglobin levels over 12.0, those whose hemoglobin levels fell to below 12.0 gms % had average <u>decreases</u> of 1.2 WPPSI points and 2.0 Lorge Thorndike points. Those whose hemoglobin levels stayed over 12.0 had average <u>increases</u> of 8.9 WPPSI points and 8.6 Lorge Thorndike points. These data are presented in Table VII.

For this group there was not statistically significant correlation between change in hemoglobin and change in IQ. The fact that of 6 whose WPPSI scores decreased, 4 were associated with a decrease in hemoglobin also fails to be statistically significant.

TABLE VII

AVERAGE CHANGES IN INTELLIGENCE TEST SCORES AMONG CHILDREN WITH FALL HEMOGLOBIN LEVELS OVER 12.0 GMS % GROUPED ACCORDING TO CHANGE IN HEMOGLOBIN LEVEL

Hemoglobin Level	Change in WPPSI Average	Range	n	Change in Lorge Thorndike Average	Range	n
Decreased to 12.0 gms % or below	-1.2	-13 +12	6	-2.0	-7 +7	6
Stayed over 12.0 gms %	+8.9	-7 +28	48	8.6	-17 +25	50

HEMOGLOBIN AND BEHAVIOR RATINGS

There were no significant differences in teachers' ratings of behavior and hemoglobin levels. Table VIII shows the average ratings for children with hemoglobin levels 12.0 gms % or below, and those with 13.0 and above. Ratings of 1 and 2 were negative (low activity, high perseveration, etc.); ratings of 6 and 7 were positive. A 4 rating was average.

TABLE VIII

AVERAGE TEACHERS RATINGS FOR CHILDREN IN HIGH AND LOW HEMOGLOBIN LEVEL RANGES

	Hb 12.0-10.0 (Average rating)	Hb 13.0-15.0 (Average rating)
Classroom activity	4.4	4.4
Playground activity	4.5	4.4
General coordination	3.7	3.9
Fine Coordination	3.9	3.7
Quickness of reaction to authority	3.7	3.9
Ability to understand directions	4.3	4.1
Attention Span	3.8	3.4
Independence in Classroom	4.5	3.9
Independence on the playground	4.5	4.0
Perseveration	4.2	4.5
Distractibility	3.8	4.0
Self Expression	4.3	3.7
Hyperactivity	4.1	3.9

ATTENDANCE

Those whose spring hemoglobin levels were below 12.0 gms % (had little or no increase) had an average winter attendance of 87 %. Those whose fall hemoglobin levels had increased by an average of .9 gms % had an average winter attendance of 84 %.

PULSE

There was no significant difference in pulse rates between the high and low hemoglobin groups.

CONCLUSIONS

Iron in the form given to Head Start children did not change hemoglobin levels, serum iron levels, or total iron binding capacity. There is the possibility that one 60 mg ferrous sulfate tablet a day at lunch or snacktime for 108 school days was not an efficient way to give iron. Teachers were certain that with the exception of three children of the 113 in the sample, the children took the pills regularly. There may be a deficiency in the absorption or ability to utilize iron.

There are indications (reported in "A Study of Food and Poverty") that iron in enriched bread was not associated with hemoglobin levels, and that either these hemoglobin levels are normal for these children at this age, or there are other complicating deficiencies instead of or in addition to iron.

The changes in hemoglobin levels were not associated with attendance. We do not know why some hemoglobins increased and some decreased. Perhaps some children had more vitality that enabled them to eat more and participate more, so that the same factor could have caused increase in hemoglobin and in IQ. Perhaps some children had chronic infections.

Changes in hemoglobin levels among those who began with low levels were associated with changes in intelligence test scores. While decreases of high hemoglobin levels to below 12.0 gms %
were associated with decreases in IQ, this association was not

significant. Perhaps the effects of decreases manifest themselves more slowly than the effects of increases.

The fact that changes in hemoglobin level (among those who began with low hemoglobins) were associated with changes in intelligence test scores indicates that hemoglobin levels affect something in the child. Children whose hemoglobin levels increased benefited more from the classroom situation than those whose hemoglobin levels decreased. Precisely what was affected was not measured: there was no significant correlation between hemoglobin levels and intelligence test scores or the teachers' ratings of behavior. Since hypoxia causes first increased nerve excitability and then decreased excitability, effects are difficult to measure.

Two Head Start teachers had experience last summer with Missoula kindergarten-age children who had had no kindergarten experience. These were predominantly children of families whose incomes were just above the poverty guidelines. The teachers noted a great difference in the classes. I pointed out that Head Start had brought Head Start children's average IQ up to 102. Did that not make them comparable to other children? According to the teachers, it did not. There was a difference in the responsiveness, in eagerness to learn, in curiosity, in something they could not define. Hemoglobin levels may affect that responsiveness.

SUMMARY

Data about hemoglobin and hematocrit levels, performance on individual and group intelligence tests, and teachers' ratings of behavior were collected for 113 Head Start children in Missoula, Montana at the beginning and end of the Head Start year, in October and May. A randomly selected experimental group received 60 mg ferrous sulfate each school day; the control group received placebos.

There was no significant difference in the changes in hemoglobin levels between the experimental group who received ferrous sulfate and the control group who received a placebo.

There was no significant relationship between fall hemoglobin levels and fall IQs or teachers' ratings of behavior, or between the spring data.

Among those children who had fall hemoglobin levels in the range of 10.0 to 12.0 gms %, there was a significant correlation of .74 between changes in hemoglobin level and changes in WPPSI scores. Those with hemoglobin changes of -1.6 to +0.1 gms % had an average increase of 2.0 WPPSI points. Those with hemoglobin changes of +0.9 to +1.9 gms % had an average increase of 14.7 WPPSI points.

Among the children who had fall hemoglobin levels over 12.0 gms %, there was not a significant correlation in changes in IQ and changes in hemoglobin levels. Those whose hemoglobin levels fell to 12.0 gms % or below had an average <u>decrease</u> of 1.2 WPPSI points. Those whose hemoglobin levels remained over 12.0 gms % had an average <u>increase</u> of 8.9 WPPSI points.

The conclusions were 1) Those children who had hemoglobin levels of 10.0 - 12.0 gms % did not have iron deficiency anemias. Low hemoglobin levels may have been caused by some deficiency other than or in addition to iron deficiency. 2) Increases in low hemoglobin levels were associated with increases in IQ.

There is a possibility that since many Head Start children eat large proportions of enriched refined carbohydrates, the probable source of most of the iron, the lower hemoglobin levels might be associated with deficiencies of pyridoxine, folic acid and vitamin B_{12}. This possibility is further discussed in the accompanying "Study of Food and Poverty".

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