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A Longitudinal Study of Dietary Intake and Influence of Iron Status on Infants' and Toddlers' Mental and Motor Development

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A LONGITUDINAL STUDY OF DIETARY INTAKE AND INFLUENCE OF IRON STATUS ON INFANTS' AND TODDLERS' MENTAL AND MOTOR DEVELOPMENT

by

Steven Matley Wood

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Steve Wood

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

LIST OF TABLES

LIST OF TABLES (continued)

ABSTRACT

A Longitudinal Study of Dietary Intake and Influence of Iron Status on Infants' and Toddlers' Mental and Motor Development

by

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Utah State University, 1989

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Thirty-two non-anemic children were assessed clinically, biochemically and anthropometrically at six months, one year and two years of age to investigate the relationship of iron status to mental and motor development. Using dietary history and dietary record instruments, dietary iron was estimated and compared to the National Food Consumption Survey (1985) and the Recommended Dietary Allowances (RDA) for corresponding age groups. The Bayley Scales of Infant Development (which assess mental and motor development) and the Caldwell Home Inventory (which evaluates the environmental stimuli) were performed and correlated with blood iron parameters, anthropometric measurements and dietary nutrient intakes.

Nutrient intakes of these children were similar to those reported in the NFCS (1985) for one- and two-year-olds. Iron intake decreased from 13.2 mg iron daily (88%

RDA) at six months to 10.3 mg iron daily (68% RDA) and 7.4 mg iron daily (49% RDA) at two years of age. The correlation between iron intake and development was not statistically significant at any age. Stepwise, multiple regression was employed to investigate the extent to which variation in mental and motor development was explained by dietary variables, blood iron parameters and anthropometric measurements. Hematocrit was the only variable that significantly explained variation in mental development at all three ages. The findings of this study were different from earlier studies in that there was no statistical correlation between iron status and mental development; but, it did confirm the conclusion of more recent experiments that iron status has little effect on infants' and toddlers' development. The finding that infants and toddlers consuming less than the RDA for iron do not display iron deficiency symptoms and were not developmentally delayed or compromised should be comforting to parents who are concerned about iron intake during this critical period of infants' brain growth.

(67 pages)

CHAPTER I

INTRODUCTION

Iron is a constituent of hemoglobin, myoglobin and a number of enzymes and, therefore, is an essential nutrient for man (National Academy of Sciences 1980). Iron plays an important role in biological oxidative and reductive processes through its ability to exchange electrons. Iron deficiency is claimed to be one of the most common nutrient deficiencies in North America (Weinberg et al. 1980). The clinical manifestations of iron deficiency have been recognized for many years: anemia, angular stomatitis, glossitis, dysphagia, hypochlorhydria, koilonychia and pica (Finch and Cook 1984; Tucker et al. 1984).

Iron deficiency crosses all socioeconomic lines but is most prevalent in the poor and in infants (Weinberg et al. 1980). This deficiency occurs most frequently in infants of 6 to 24 months of age (Dallman et al. 1980; Lozoff and Brittenham 1986). This is due to the infants' high demand for iron to maintain rapid growth and is essential for bodily processes. If an infant's iron stores are depleted and not restored through the diet during this critical time, overt clinical signs of iron deficiency are observed. With this potential deficiency in mind, one must be particularly concerned with this high-risk group and the effect and outcome of inadequate iron supplies on bodily functions.

Iron functions as an oxygen transporter in the blood through hemoglobin; by this means, oxygenation occurs throughout the body. One organ that requires a high amount of oxygen is the brain. The critical period for brain growth is the first six months to two years of age. Therefore, iron deficiency during this critical period may have lasting effects.

Cook and Finch (1979) proposed a three-stage scheme to clarify iron deficiency: The first stage occurs when there is a reduction of iron stores (often called iron depletion). In this stage serum ferritin falls approximately in proportion to non-heme iron stores. The second stage, known as iron deficient erythropoiesis, manifests itself when iron stores are completely exhausted and hemoglobin synthesis is impaired. It is in this stage that erythrocyte porphyrin levels increase and transferrin saturation falls. Hemoglobin level drops slightly during this stage but can be increased fairly rapidly with iron therapy. The third stage is characterized by an iron restriction to the bone marrow, causing hemoglobin levels to fall below the acceptable range. The result of this stage is "iron deficiency anemia." A concern of iron deficiency is that an individual exhibits deficiency symptoms in the third stage, but other alterations, particularly in the brain, may be manifest at stages one and two without any clinical indications of the impact of the deficiency (Cook and Finch 1979).

Recently, researchers have suggested that iron deficiency may be associated with "soft symptoms" such as loss of energy, easy fatiguability, lack of concentration, irritability, poor school performance and anorexia (Oppenheimer and Hendrickse 1983). Noting these soft symptoms, one may consider that they are the result of iron deficiency on the brain. "Behavioral effects of iron deficiency are potentially the most worrisome manifestations of the 'commonest [sic] nutritional disorder' in the world" (Lozoff et al. 1987, p. 981).

"An adverse effect of iron deficiency on the central nervous system has long been suspected but systematic study of possible effects has only recently begun" (Oppenheimer and Hendrickse 1983, p. 590). Dallman and Schwartz (1965) emphasized that "susceptibility of a given tissue to iron lack is a product of organ dysfunction, growth rate and cell turnover" (Dallman and Schwartz 1965, p. 1638). The concern about iron deficiency in infancy is further emphasized by the fact that the "unfolding of fundamental mental and psychomotor processes coincide with the period in which iron deficiency anemia is most prevalent" (Lozoff et al. 1987, p.981).

Statement of the Problem:

Infants ranging from 6 to 24 months of age are at risk of developing iron deficient anemia as the result of their rapid growth and low intake of iron. This risk period coincides with the time when the brain is going through a rapid growth phase. Therefore, the possibility of life-long mental effects as a result of iron deficiency during this critical period, without clinical symptoms, warrants investigation.

This study was conducted to evaluate and determine dietary intake of infants who were followed for 18 months. Dietary iron and iron status were correlated and assessed for their influence on the infants' development at six months, one year and two years of age.

Objectives of the Study:

1. To assess the iron status of 30 infants at birth through cord blood ferritin and other blood parameters of iron status.
2. To determine and evaluate 30 infants' nutrient intake at six months, one year and two years of age. These intakes were then compared to The National Food Consumption Survey (1985) (NFCS) and the Recommended Dietary Allowances (RDA). This was accomplished through the tools of diet histories and food frequencies, which were analyzed by the National Livestock and Meat Board Nutrition Information System Data Base.
3. To determine the correlations of hematocrit and iron intake with mental and psychomotor development by using the Bayley Scales of Infant Development (BSID) at six months, one year and two years of age. Also, to correlate development with the Caldwell Home Inventory Test.
4. To determine the correlation of the infants' iron intake with hematocrit, mean cell volume (MCV), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC), red cell distribution width (RDW), unsaturated iron binding capacity (UIBC), total iron binding capacity (TIBC), serum iron and ferritin at two years of age.

5. To assess the influence of iron parameters, nutrient intake and anthropometric measurements on mental and psychomotor development by means of a forward stepwise, multiple regression method.

Limitations of the Study:

1. Data were collected on 32 subjects all living in the same geographical location. This presents a limitation of small sample size and may not be a true representation of the population of infants and toddlers ranging from six months to two years of age. However, nutrient intakes were similar to NFCS (1985).
2. Iron status was evaluated through hematocrit, which is not very sensitive to small changes in iron stores.
3. None of the subjects were severely anemic and none scored abnormally low on the BSID test.

CHAPTER II

LITERATURE REVIEW

Iron deficiency could impair the development of the central nervous system and/or cause behavioral changes in several hypothetical ways: 1) Iron is required for DNA synthesis; hence, iron deficiency early in life might impair neuronal growth. 2) Several of the enzymes involved in neuro-transmission are iron dependent, including monoamine oxidase (Youdim et al. 1980). It has been suggested that the behavioral observations and low performance scores observed in iron deficient children may be related to excessive production of catechol (Voorhess et al. 1975) secondary to reduction in monoamine oxidase activity. Another biochemical alteration in the iron deficient brain is the decreased activity of aldehyde oxidase, which enzyme is responsible for the degradation of serotonin (Mackler et al. 1978). 3) Iron deficiency leads to an excess of certain porphryins which may cause behavioral changes comparable with those observed in other conditions where excess heme precursors are found, namely lead poisoning and acute intermittent porphyria (Leibel 1977).

Rat Studies:

Initially, it was thought that brain growth in humans occurred primarily before birth, whereas rats' brain maturation occurs postnatally (Dobbing 1971). Recent observations indicate that the maturation and growth of the human brain and the rat brain have similar aspects. Five-sixths of the human brain growth spurt is postnatal, the majority occurring in the first two years of life (Dobbing and Sands 1973). Rat brain growth is most rapid in the first ten days of life (Dobbing 1971). Considering the fact that the time of brain maturation is slower in humans than in rats, the effect of postnatal iron deficiency in rats may be an indication of deleterious effects in humans.

The effect of iron deficiency on behavior and development has been noted in rats (Dallman and Schwartz 1965; Findlay et al., 1981; Weinberg et al., 1980) Behavioral development studies have been conducted since it was observed that there is a slower rate of iron turnover in the brain (Dallman and Spirito 1977). Dallman and Schwartz (1965) investigated iron concentration in various tissues of iron deficient rats and compared these concentrations to those in control rats at 28 and 48 days of age. They found that iron deficient rats have low brain non-heme iron and brain hemoglobin concentrations as well as reduced concentrations of blood ferritin and blood hemoglobin. An iron deficient state was confirmed by low serum ferritin levels and low liver iron concentrations. The researchers then administered 5 mg of iron intramuscularly daily. After a short period of iron administration, the liver non-heme and hemoglobin concentrations returned to normal, but the brain non-heme iron and brain ferritin levels remained depressed. This indicated that an iron deficiency in infancy may affect brain iron concentrations and might not be overcome even with iron supplementation. Thus, iron deficiency early in life might cause deleterious effects on development that cannot be corrected. Similar findings have been reported that magnify the concern that iron deficiency early in life may have long-lasting, harmful effects on development (Dallman et al. 1975; Dallman and Spirito 1977; Findlay et al. 1981; Weinberg et al. 1979).

Weinberg et al. (1980) demonstrated that decreased brain iron concentrations caused by an iron deficient diet lead to differences in behavioral tasks as compared with a control (adequate iron) group. Weinberg concluded that, "Iron deficiency may reduce an animal's general responsiveness to environmental stimulus" (Weinberg et al. 1980, p. 493).

Having reviewed adverse effects of iron deficiency in young animals, the focus of the literature review will now be directed to deleterious developmental and behavioral effects of iron deficiency in human infancy.

Human Infant Studies:

Cantwell (1974) attempted to determine if iron deficiency anemia during infancy causes noticeable behavioral changes later in life. He observed that infants which were from the same socioeconomic group and had been evaluated for anemia between 6 and 18 months showed delayed neurological development when assessed between 6 and 7 years of age. Cantwell concluded that "soft" neurological signs or changes due to iron deficiency anemia in infancy are detected as clumsiness in balancing on one foot, tandem walking and repetitive hand movements (mainly motor development). Cantwell also concluded that "Anemia in infancy appears to cause a permanent minimal brain dysfunction" (Cantwell 1974, p.342).

Recently, Lozoff et al. (1987) conducted a study on 191 infants in Costa Rica in which iron deficient anemic infants demonstrated significantly lower mental and psychomotor test scores than non-anemic infants. This was shown through the administration of the Bayley Scales of Infant Development before and after supplementation of iron. The researchers concluded that after three months of iron supplementation lower scores on the mental and psychomotor areas of the test were raised in 36 percent of the infants whose anemia and iron deficiency were corrected. However, 64 percent of the more severely iron deficient individuals had significantly lower scores, even after the iron therapy (Lozoff et al.

1987). This implies that low iron status during the critical period of brain growth may have lasting effects.

Oski and associates (1983) hypothesized that an infant who is not identified as anemic through clinical measurements, may show behavioral changes. These researchers observed infants ranging from 9 to 12 months who were non-anemic (hemoglobin greater than 11.0 grams/dL) but were classified as iron sufficient or iron deficient by serum ferritin concentration, erythrocyte proporphyrin values and mean cell volume of erythrocytes. Each individual was evaluated by the Bayley Scales of Mental Development, treated with iron (intramuscularly) and retested for development after seven days. Oski et al. (1983) concluded "That iron deficiency, even in the absence of anemia, results in biochemical alterations that impair behavior in infants" (Oski et al. 1983, p. 877). Similarly, other studies (Honig and Oski 1978; Lozoff et al. 1982; Lozoff et al. 1987; Oski and Honig 1978; Walter et al. 1983) have been conducted of iron deficiency and its effect on behavior and mental development but have focused mainly on short-term iron supplementation and its effect on mental development. These researchers found a positive correlation between iron supplementation and mental development. Others noted that low iron status in infancy is correlated with low IQ or impaired development later in life (Palti et al. 1983;

Palti et al. 1985). However, evidence has also been presented that iron status does not affect infant development (Deinard et al. 1981; Deinard et al. 1986).

CHAPTER III

METHODOLOGY

Subject Recruitment:

Subjects were recruited through local physicians' offices. The criteria included mothers who were para II or greater. This was imposed to decrease variation between para I and multiparous mothers in child rearing and interaction practices. The subjects were limited to mothers with no history of anemia and those with no prior history of miscarriages or of children born with congenital malformations. Over 1,000 mothers were screened. Their infants were followed from birth to two years of age. The term infant is used to describe children from birth to six months of age. Toddlers describes children from six months to two years of age.

Methods and Procedures:

All potential subjects were referrals from local physicians' offices. Mothers were contacted by telephone and informed about the study. The mothers were asked to meet at a local hospital, where the study was presented, rights of the subjects were explained and consent forms signed (Appendix A).

Iron stores of all infants were evaluated at birth by cord blood iron parameters: hematocrit, serum iron, TIBC, ferritin and percent saturation. At six months, one year and two years of age, anthropometric measurements were performed, including height, weight and head circumference. Height was determined using a recumbent length board. The infant's head was placed snugly against the head board and the sliding foot board was adjusted to rest against the infant's feet. The measurements were recorded in inches. The weight of each infant, dressed in light-clothing and a dry diaper, was measured to the nearest ounce using an infant scale. Head circumference was measured using a flexible, non-stretchable measuring tape. Values were recorded to the nearest 0.1 centimeters.

The infants' diet histories were obtained from the mothers, who were asked to report breast-feeding and bottle-feeding practices. The quantities of formula as well as other foods, including vitamin and mineral supplements, were recorded. Dietary record instruments were the same as those used by Anderson (1987) (see Appendix B). Blood samples were obtained through heel pricks and analyzed for hematocrit. Hematocrit (percent of packed red blood cells in whole blood) was determined by centrifugation. When an infant was one year of age, a one-day diet history was taken and blood samples were obtained. A three-day diet record was recorded at two years of age. Blood was drawn by venous puncture, and a complete iron panel was performed. By use of a radioimmunoassay procedure (RIA kit commercially prepared by Diagnostic Products), serum ferritin concentrations were measured.

Nutritional content of reported foods was evaluated using the National Livestock and Meat Board Nutrition Information System data base. This data base was compiled from the United States Department of Agriculture's (USDA) 1986 Nationwide Food Consumption Surveys. There are 30 nutrients that can be analyzed on this data base. Nutrients analyzed in this study were: energy, protein, fat, carbohydrate, cholesterol, calcium, iron, magnesium, phosphorus, zinc, copper, potassium, sodium, vitamin A, carotene, vitamin E, vitamin C, thiamin, riboflavin, niacin, vitamin B_6, folacin and vitamin B_{12}.

The infants' and toddlers' nutrient intakes were compared to the age respective NFCS (1985) groups. The NFCS (1985) was used as a comparison because it was the most recent survey which separated infants and toddlers according to age (the preliminary data reports groups all children together as children 1-3 years of age or children 1-5 years of age). This comparison was performed to determine nutrient intake similarities or differences among subjects polled across the nation. Because the NFCS (1985) did not include vitamin and mineral supplements in the summary data, vitamin and mineral supplementation was not included when comparing nutrient intake to RDA and NFCS (1985) but was included in determining correlation of nutrient intakes with mental and motor development.

The Bayley Scales of Infant Development (BSID) were administered within two weeks of six months, one year and two years of age. Mental and motor development were estimated using the two indices of the test.

> (1) The Mental Scale is designed to assess sensory-perceptual acuities, discriminations, and the ability to respond to these; the early acquisition of 'object constancy' and memory, learning, and problem solving ability; vocalizations and the beginnings of verbal communication; and early evidence of the ability to form generalizations and classifications, which is the basis of abstract thinking. Results of the administration of the Mental Scale are expressed as a standard score, the MDI, or Mental Development Index.
>
> (2) The Motor Scale is designed to provide a measure of the degree of control of the body, coordination of the large muscles and finer manipulatory skills of the hands and fingers. As the Motor Scale is specifically directed towards behaviors reflecting motor coordination and skills, it is not concerned with functions that are commonly thought of as 'mental' or 'intelligent' in nature. Results of the administration of the Motor Scale are expressed as a standard Score, the PDI, or Psychomotor Development Index (Bayley 1969, p. 3).

The BSID was used to assess infant development because of its frequent use in other studies and its high reliability coefficients (Bayley 1969). The scale is described to represent infants' and toddlers' development in the United States. This scale includes an average score of 100, a standard deviation of 16 and a range from 50 to 150.

Statistical Analysis:

Statistical analysis was performed through the use of the Number Cruncher Statistical System (Hintze 1987). Means, standard deviations and ranges were generated for all quantitative measurements. Correlation matrices for all variables, by ages of subjects, were generated to evaluate significant relationships among mental/psychomotor development, nutrient intakes, anthropometric measurements and biological parameters. Multiple regression techniques, which included forward stepwise regression, were implemented to evaluate relationships among dietary, anthropometric and hematologic parameters in determining mental and psychomotor development.

CHAPTER IV

RESULTS AND DISCUSSION

Demographical Data:

The study population consisted of 32 infants (15 males and 17 females) living in Cache Valley. The infants were observed at six months, one year and two years of age. Mothers ranged from 20 to 35 years of age with an average of 26.6 years when the infants were born. All mothers were multiparous with an average of 2.2 children (range 1-4 children).

Family income ranged from $10,000 to $40,000 per year. Forty-one percent of the subjects' families reported an annual income in the range of $15,000 to $20,000 (n=13).

Mothers' education levels were considered presuming that the mothers would be the primary caretakers of the subjects for the first two years of life. All mothers had completed high school with five having completed Bachelor's Degrees. The majority of the mothers (n=23) were homemakers while the others were employed at skilled (n=6) or professional jobs (n=3) (table 1).

Table 1. The family income, education level and occupation of subjects' mothers (n=32)

Family Income (dollars)	n	Percent of Subjects
10,001-15,000	4	12.5
15,001-20,000	13	40.6
20,001-25,000	6	18.8
25,001-30,000	6	18.8
30,001-35,000	3	9.4
Highest Level of Mother's Education Level		
High School	11	34.4
1 year college	10	31.3
2 years college	5	15.6
3 years college	1	3.1
B.S. degree completed	5	15.6
Occupation of Mothers		
Skilled	6	18.8
Professional	3	9.4
Homemaker	23	71.9

Birth Data:

The estimated gestational age average was 39.6 ± 1.6 weeks (range 34.5 - 42 weeks); however, 30 of the subjects were born between 38 and 42 weeks of gestation. Birth weights ranged from 4 pounds 11 ounces to 9 pounds. The average birth weight for boys was 7 pounds 9.7 ounces while the average for girls was 7 pounds 7.7 ounces. The average length was 20.5 inches (range of 18 to 22 inches). Blood values from the umbilical cord are noted in table 2. When considering all the blood iron parameters of an individual together, as encouraged by Lanzkowsky (1985), no indication of iron deficiency anemia was determined from the cord blood iron parameters even though one parameter may be indicative of iron deficiency. For example, the infant which had a 12 percent saturation level, which if considered alone, would indicate iron deficiency, however hematocrit, serum iron, UIBC, TIBC and ferritin being 14.9 (%), 31 (ug/dL), 258 (ug/dL) and 80 (ng/mL) respectively indicated adequate iron status. This consideration was performed on all infants which had low values of hematocrit, serum iron, TIBC, UIBC and saturation.

Table 2. Cord blood iron parameters at birth

	n	Mean & S.D.	Range
Hematocrit (%)	31	46.2 ± 4.4	34.5 - 52.1
Serum Iron (ug/dL)	29	160.0 ± 57.1	31.0 - 319.0
TIBC (ug/dL)	28	303.7 ± 91.2	207.0 - 594.0
Ferritin (ng/mL)	29	107.4 ± 211.0	27.0 - 211.0
Saturation (%)	28	52.7 ± 20.1	12.0 - 83.5

Nutrient Intake Data:

Six-month-Olds
Dietary Intake Data:

The infants' nutrient intake at six months of age with ranges and percent of RDA are noted in table 3.

Table 3. The dietary intake of infants at six months of age with average nutrient intake, standard deviations and percent of RDA*

	Mean & SD	Range	% RDA
Energy (Kcals)	770 ± 130	545 - 1230	100
Protein (gm)	15 ± 6	9 - 42	106
Fat (gm)	38 ± 9	22 - 59	-
Carbohydrate (gm)	92 ± 22	51 - 148	-
Cholesterol (mg)	83 ± 50	0 - 152	-
Calcium (mg)	556 ± 258	279 - 1550	103
Iron (mg)	13.2 ± 9.7	0.3 - 36.8	88
Magnesium (mg)	77.3 ± 34.	3.7 - 185.7	110
Phosphorus (mg)	77 ± 232	139 - 1210	105
Potassium (mg)	905 ± 353	506 - 2030	-
Sodium (mg)	241 ± 114	130 - 619	-
Zinc (mg)	3.9 ± 2.0	1.1 - 8.7	77
Copper (mg)	0.6 ± 0.2	0.1 - 1.3	-
Vitamin A **(IU)	5120 ± 4400	910 - 16700	256
Carotene (RE)	331 ± 471	0 - 1670	-
Vitamin E (mg)	10.2 ± 3.2	0.3 - 16.9	250
Vitamin C (mg)	97.5 ± 50.0	10.8 - 200.8	279
Thiamin (mg)	0.7 ± 0.6	0.10 - 3.1	148
Riboflavin (mg)	1.1 ± 0.6	0.4 - 2.4	187
Niacin (mg)	8.3 ± 4.9	1.8 - 20.0	104
Vitamin B_6 (mg)	0.4 ± 0.3	0.1 - .9	70
Folacin (ug)	98 ± 58	34 - 230	219
Vitamin B_{12} (ug)	1.6 ± 1.3	0.4 - 4.5	105

*n=32, Does not include vitamin and mineral supplements, however, three infants were supplemented

**1 I.U. of Vitamin A=5 R.E. of Vitamin A

Nutrients that were below 100% of the RDA were iron, zinc, and vitamin B_6. Mean iron and zinc concentrations were skewed to the left (or lower end) because of the low concentrations of iron and zinc found in human breast milk. Percent of the total energy being supplied from fat, carbohydrate and protein were 44, 48 and 8 percent respectively.

One-Year-Olds'
Dietary Intake Data:

One-year-olds' nutrient intake data are presented as means, ranges and percent of RDA in table 4.

Table 4. The dietary intake of toddlers at one year of age with average nutrient intake, standard deviations and percent of RDA*

	Mean & SD	Range	% RDA
Energy (Kcals)	1080 ± 330	595 - 2280	83
Protein (gm)	42 ± 19	12 - 102	181
Fat (gm)	44 ± 18	15 - 97	-
Carbohydrate (gm)	130 ± 35	82 - 251	-
Cholesterol (mg)	208 ± 147	22 - 556	-
Calcium (mg)	927 ± 432	266 - 2560	116
Iron (mg)	10.3 ± 7.2	2.0 - 32.9	68
Magnesium (mg)	59.0 ± 62.4	58.6 - 343.8	106
Phosphorus (mg)	880 ± 398	220 - 2212	110
Potassium (mg)	1705 ± 640	660 - 3910	-
Sodium (mg)	1170 ± 550	230 - 2400	-
Zinc (mg)	6.2 ± 3.5	1.9 - 19.8	62
Copper (mg)	0.6 ± .3	0.3 - 1.6	-
Vitamin A *(IU)	5020 ± 2890	1370 - 14710	251
Carotene (RE)	340 ± 280	40 - 1200	-
Vitamin E (mg)	5.5 ± 4.3	0.3 - 14.7	110
Vitamin C (mg)	82.2 ± 64.7	12.1 - 290.0	183
Thiamin (mg)	0.9 ± 0.5	0.2 - 3.1	123
Riboflavin (mg)	1.7 ± .9	0.5 - 5.5	208
Niacin (mg)	9.0 ± 4.9	0.5 - 24.5	100
Vitamin B_6 (mg)	0.8 ± 0.4	0.4 - 2.1	91
Folacin (ug)	126 ± 77	48 - 408	126
Vitamin B_{12}(ug)	3.4 ± 2.2	0.6 - 12.1	172

*n=32, Does not include vitamin and mineral supplements, however, two toddlers were supplemented

**1 I.U. of Vitamin A=5 R.E. of Vitamin A

Nutrients that were below 100% of the RDA were energy, iron, zinc, and vitamin B_6. Percent of the total energy being supplied by fat, carbohydrate and protein were 37, 47 and 16 percent respectively. The RDA, average nutrient consumption of this study and nutrient consumption of the (1985) USDA National Food Consumption Survey for toddlers (one-year-olds') are depicted in appendix C. This comparison indicates that the subjects included in this study and those in the NFCS consumed similar levels of nutrients.

Two-Year-Olds'
Dietary Intake Data:

Table 5 contains the two-year-olds' dietary intake expressed as averages, standard deviations, ranges and percent of the RDA.

Table 5. The dietary intake of toddlers at two years of age with average nutrient intake, standard deviations and percent of RDA*

	Mean & SD	Range	% RDA
Energy (Kcals)	1120 ± 170	800 - 1430	86
Protein (gm)	39 ± 9	16 - 56	169
Fat (gm)	41 ± 11	22 - 73	-
Carbohydrate (gm)	148 ± 24	97 - 196	-
Cholesterol (mg)	166 ± 87	42 - 373	-
Calcium (mg)	714 ± 208	249 - 1160	89
Iron (mg)	7.4 ± 1.8	4.3 - 11.6	49
Magnesium (mg)	148.2 ± 26.1	105.3 - 198.1	99
Phosphorus (mg)	770 ± 160	370 - 1080	97
Potassium (mg)	1510 ± 370	555 - 2280	-
Sodium (mg)	1565 ± 490	650 - 2440	-
Zinc (mg)	5.3 ± 1.3	2.1 - 8.2	53
Copper (mg)	0.6 ± 0.1	0.4 - 0.8	-
Vitamin A *(IU)	3860 ± 3460	1490 - 16690	193
Carotene (RE)	226 ± 362	22 - 1580	-
Vitamin E (mg)	3.6 ± 1.6	1.2 - 8.2	72
Vitamin C (mg)	57 ± 38	17 - 150	127
Thiamin (mg)	0.8 ± 0.2	0.5 - 1.2	120
Riboflavin (mg)	1.3 ± 0.3	0.8 - 2.1	165
Niacin (mg)	9.2 ± 2.0	5.5 - 12.5	102
Vitamin B_6 (mg)	0.9 ± .2	0.5 - 1.4	100
Folacin (ug)	135 ± 43	59 - 212.5	135
Vitamin B_{12} (ug)	2.8 ± 0.7	1.5 - 4.3	140

*n=26, Does not include vitamin and mineral supplements, however, one toddler was supplemented

**1 I.U. of Vitamin A=5 R.E. of Vitamin A

Nutrients consumed below 100 % of the RDA included energy, calcium, iron, zinc, and vitamin E. It is important to note that mean iron intake decreased from six months (88% of RDA), one year (69% of RDA) and at two years (49% of

RDA). This indicates an area of concern. Infants in this critical period have a consistent decrease in iron intake as well as an increased iron need to sustain growth.

The percent of the total energy being supplied by fat, carbohydrate and protein were 33, 53 and 14 percent respectively. The RDA, nutrient consumption of toddlers of this study and the (1985) USDA National Food Consumption Survey Nutrient Intake for Children, age two, are compared in appendix C. The reported nutrient consumption of two-year-olds by NFCS (1985) did not include vitamin and mineral supplements; therefore, supplements are not included in this comparison.

Feeding Practices:

Breast feeding was compared with formula and milk feeding to determine differences in growth patterns, hematocrit, mental development and motor development (table 6).

Table 6. Milk sources and growth parameters as well as Mental Development Index (MDI) and Psychomotor Development Index (PDI)

	n	Ht	Wt	OFC	MDI	PDI	Hct
Six-Month-Olds:							
Breast Milk	15	25.8	16.4	43.6	99	106	37.9
Formula w/ Fe	8	26.2	17.4	43.1	101	110	38.0
Formula w/o Fe	7	26.1	16.6	43.5	99	103	36.6
Whole Milk	0	-	-	-	-	-	-
2 % Milk	2	26.7	17.6	44.4	95	100	36.0
1 % Milk	0	-	-	-	-	-	-
One-Year-Olds:							
Breast Milk	5	28.5	18.6	46.6	111	102	36.9
Formula w/ Fe	2	30.2	25.0	46.3	116	114	36.4
Formula w/o Fe	4	29.6	21.9	46.1	111	101	35.4
Whole Milk	8	28.7	20.5	45.3	115	95	36.5
2 % Milk	12	29.5	21.7	46.4	109	103	37.0
1 % Milk	1	29.3	23.8	45.5	109	105	36.0
Two-Year-Olds:							
Breast Milk	0	-	-	-	-	-	-
Formula w/ Fe	0	-	-	-	-	-	-
Formula w/o Fe	0	-	-	-	-	-	-
Whole Milk	5	33.7	26.7	49.2	122	118	37.9
2 % Milk	14	33.7	27.8	49.0	112	121	38.9
1 % Milk	4	34.0	27.5	49.3	116	100	35.4

No statistical differences were noted among subjects consuming different milk sources for anthropometric measurements, mental development or hematocrit values within the three age periods. No noticeable patterns were evident in terms of growth or development. It is felt that this is a result of too few subjects within each group.

Anthropometry Data:

Boys and girls were separated in terms of height, weight and head circumferences to determine deviation from normal infants' and toddlers' growth patterns (table 7).

Table 7. Mean anthropometric data of subjects (girls and boys separated) at six months, one year and two years of age (normal ranges in parenthesis)*

	Six Months	One Year	Two Years
Girls:			
Height	25.7 (25.2-26.5)	28.8 (28.5-30.0)	32.7 (32.5-35.0)
Weight	17.0 (14.5-17.2)	21.1 (19.5-22.5)	27.6 (24.4-28.0)
**OFC	43.2 (41.5-43.3)	45.8 (44.8-46.4)	48.8 (47.4-49.0)
Boys:			
Height	26.4 (25.5-27.2)	29.7 (29.0-31.5)	34.8 (33.6-35.4)
Weight	16.7 (15.9-18.5)	21.3 (21.0-24.0)	27.5 (25.5-31.5)
**OFC	43.8 (42.6-44.5)	46.4 (46.0-47.9)	49.4 (48.8-50.2)

*n=17 for girls and n=15 for boys at six months and one year of age
n=14 for girls and n=12 for boys at two years of age

**OFC=Occipital-Frontal Bone Circumference (Head Circumference)

There are small differences between girls' and boys' anthropometric averages; however, the averages were all within the normal limits for age.

Hematocrit Data and Iron Parameters:

The hematocrit values of the infants and toddlers were similar at the three different times (table 8). These values do not indicate iron deficiency anemia even though the subjects' diets were particularly low at two years of age, in terms of dietary iron as compared to the RDA.

Table 8. Means, standard deviations, maximum and minimum hematocrit concentrations at six months, one year and two years of age

	n	Mean & Std Dev	Min.	Max.
Six-month-olds	32	37.5 $\pm$ 2.73	33.0	44.7
One-year-olds	32	36.6 $\pm$ 2.42	31.5	41.6
Two-Year-olds	26	36.9 $\pm$ 2.70	33.2	43.3

A correlation matrix of iron intake and hematological parameters of iron status of two-year-olds is presented in table 9.

Table 9. **Correlation matrix of iron intake and hematological parameters of two-year-olds**

	Iron Intake	Hct	Ferritin	MCV	MCH	MCHC	RDW	Serum Iron	UIBC	TIBC
Iron Intake	1.000									
Hct	.327*	1.000								
Ferr	-.139	-.140	1.000							
MCV	.016	-.006	-.009	1.000						
MCH	-.039	.011	.158	.919*	1.000					
MCHC	-.020	.034	.287*	-.524*	-.170	1.000				
RDW	-.079	.069	-.286*	-.453*	-.467*	.125	1.000			
Serum Iron	.213	.053	.099	.030	.153	.310*	-.051	1.000		
UIBC	-.102	.060	.099	-.054	.013	.315*	.317*	.220	1.000	
TIBC	.124	-.196	.535*	.226*	.337*	.203	-.267*	.109	.393*	1.0

n=26
* Significant Correlation at alpha level .05

Iron Intake = Dietary Iron Intake
Hct = Hematocrit
Ferr = Ferritin
MCV = Mean Corpuscular Volume
MCH = Mean Corpuscular (erythrocyte) Hemoglobin
MCHC = Mean Corpuscular (erythrocyte) Hemoglobin Concentration
RDW = Red Blood Cell Distribution Width
Serum Iron = Serum Iron
UIBC = Unbound Iron Binding Capacity
TIBC = Total Iron Binding Capacity

It is interesting that the only variable correlated with iron intake at an alpha level of .05 was hematocrit. It is felt that this is merely a coincidence since other researchers (Cook and Finch 1979) feel that ferritin or TIBC is a better measure of iron intake and iron stores. The other significant correlations were mainly due to the fact that the values from one parameter were used to calculate another parameter (i.e. TIBC = Iron + UIBC).

Mental and Motor Development Data:

Mental and Psychomotor scores from the BSID at six months, one year and two years of age are presented in table 10. One subject tested 150 points (which is a ceiling score) in MDI and another subject tested 150 points in PDI. Both scores were at two years of age. These ceiling values were used for statistical purposes even though their development may be higher than the scale indicates.

Table 10. Bayley Scales of Infant Development Mental (MDI) and Psychomotor (PDI) scores of subjects at six months, one year and two years of age

	n	Mean and S.D.	Range
6 Month MDI	32	99.0 ± 9.4	84-120
1 year MDI	32	111.6 ± 8.6	96-130
2 year MDI	26	116 ± 16.8	91-150*
6 Month PDI	32	105.7 ± 8.7	92-127
1 year PDI	32	101.4 ± 11.04	75-122
2 year PDI	26	116 ± 13.8	99-150*

*A Score of 150 is ceiling score

An evaluation of the subjects' environment was performed through the Caldwell Home Inventory at six months of age. This inventory quantifies the emotional and verbal responsiveness of the parents, acceptance of child's behavior, organization of the environment, provisions for play materials, parental involvement and opportunities for variety (Caldwell and Bradley 1984). Scores may range from 0-45; the average Home inventory score was 38.1 (range of 23-45). The lowest score was 23 which indicated an adverse environment for stimulation and its influence on development and learning; however, this individual did not have scores from the BSID indicating developmental delay. The Caldwell Home scores evaluated in this study are similar to Caldwell Home scores observed by Lozoff et al. (1987). The Caldwell Home Inventory was statistically non-significant when correlated with MDI and PDI at six months, one year and two years of age.

Correlations of mental and psychomotor development with iron intake at six months, one year and two years are presented in table 11.

Table 11. Correlations of Mental and Psychomotor development with iron intake at six months, one year and two years of age*

	Iron Intake	
6 Month MDI	-0.0868	p=0.6245
1 Year MDI	-0.2012	p=0.3047
2 Year MDI	-0.0465	p=0.8331
6 Month PDI	0.0012	p=0.9948
1 Year PDI	0.1529	p=0.4372
2 Year PDI	0.1948	p=0.3732

*n=32 at six months and one year of age
n=26 at two year of age
Table does include iron supplementation

There were no statistically significant correlation between iron intake and mental or psychomotor development. This indicates that this sample set's iron intake had little influence on explaining the variation of MDI and PDI scores.

A forward stepwise regression procedure was performed with all dietary, anthropometric and biochemical variables, the dependent variable being Mental Development Index or

Psychomotor Development Index. The only iron status variable which showed any useful trend in predicting MDI was the hematocrit values. Once the model was determined by this method, the iron intake variable was added to note its influence in explaining the developmental index variable (table 12). No variables were useful in predicting PDI.

Table 12. Predictability of variables on Mental Development Index at six months of age*

Variables in Equation	Beta	T	p-value
Hematocrit at 6 months	-0.9928	-1.61	0.1193
Iron Intake at 6 months	-0.1125	-0.64	0.5291

R square =0.0945
*n=32

From the stepwise regression method of analysis it was determined that hematocrit demonstrated a trend in predicting mental development. Iron intake did not influence mental development, as noted by the low p-value. In this study there was not a significant correlation between mental development and physical development this confirmed the earlier finding of Lozoff et al. (1987).

A forward stepwise regression procedure was performed with all dietary, anthropometric and biochemical variables, the dependent variable being Mental Development Index or

Psychomotor Development Index for the toddlers at one year of age. The only variables which showed any useful trend in predicting MDI were hematocrit values, carbohydrate intake, carotene intake, and riboflavin intake. With the model determined, the iron intake variable was added to evaluate its influence in explaining the Mental Developmental Index variable (table 13). The Variables which were useful in predicting PDI included: height, hematocrit, vitamin A and folacin (table 14).

Table 13. Predictability of variables on Mental Development Index at one year of age*

Variables in Equation	Beta	T	p-value
Hematocrit at 1 year	-1.2700	-2.73	0.0126
Carbohydrate Intake	0.1774	3.19	0.0044
Carotene Intake	-0.0167	-3.19	0.0044
Riboflavin Intake	4.0990	-2.02	0.0563
Iron Intake	-1.6248	-0.72	0.4819

R square = 0.5949
*n=32

Table 14. Predictability of variables on Psychomotor Development Index at one year of age*

Variables in Equation	Beta	T	p-value
Height at 1 year	4.8545	2.89	0.0086
Hematocrit at 1 year	-1.6041	-2.41	0.0248
Folacin Intake	0.0783	2.32	0.0302
Iron Intake	-0.0237	-1.05	0.3047

R square = 0.5474
*n=32

The same forward stepwise regression procedure which was performed at six months and one year of age was implemented on the data from the two-year-olds'. The only variables which showed any useful trend to predict MDI were hematocrit values and vitamin B_6 (table 15). No variables were useful in predicting PDI.

Table 15. Predictability of variables on Mental Development Index at two years of age*

Variables in Equation	Beta	T	p-value
Hematocrit at 2 years	2.6311	2.16	0.0453
Vitamin B_6	-38.3066	-2.52	0.0219
Iron Intake	-0.7502	-0.41	0.6904

R square = 0.3852
*n=26

It is important to observe that iron intake was insignificant in explaining the mental or motor development at any of the three ages. Possibly this is because the iron intake was determined, but no estimations of actual iron absorption were performed. This calculation was not performed because of the interaction which other nutrients which influence iron absorption as well as the individual's iron status contributes to the effectiveness of iron absorption. It is interesting that hematocrit, one parameter in determining iron status, was useful in predicting MDI in six-month-olds, one-year-olds and two-year-olds. This was also found in older children in a study by Hendricks et al. (1980). This may indicate oxygen carrying capacity and its correlation to mental development in children. Another possibility is that the hematocrit values may be related to a genetic developmental factor.

This study's finding, that iron intake and development were poorly correlated, is different from other studies (Oski et al. 1983; Honig and Oski 1978; Lozoff et al. 1982; Lozoff et al. 1987). A possible reason for this discrepancy is that these studies were short-term and used iron supplementation to note the effect of iron on brain development. The present study only observed correlations of iron intake and mental development. This study was unique in that it followed the same subjects from birth to two years of age and was concerned with iron status and mental development as opposed to supplementation and its effects. This study did not have any individuals who were severely iron deficient. Subjects consuming low intakes of energy, protein and/or iron were evaluated to see if there were any trends demonstrating low developmental index scores. This was performed because low energy or protein may adversely affect mental development which could mask the effect iron on brain development. However, the results indicated that the subjects who had low intakes of these nutrients were not the individuals consistently scoring low on MDI or PDI.

The findings presented in this study are similar to Deinard et al. (1981, 1986). It is presumed that because of the small sample and the various influences which aid in the development of a human being, the parameters used were not sensitive enough to identify any actual correlations between iron and mental or motor development. This finding, if confirmed by other researchers, indicates that children consuming less than the RDA for iron are not necessarily developmentally delayed or compromised.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

This study was performed to examine iron intake and brain development realizing that from 6 months to 24 months of age infants generally have low iron intake as well as an increased iron need. Also this 18 month period coincides with a phase of rapid brain growth. The population sample group's nutrient intake was similar to the same age group reported for the 1985 NFCS. The average iron intake decreased from 88 percent of RDA to 49 percent from six months to two years of age. However, there were no significant correlations between iron intake and mental or psychomotor development. The finding that infants and toddlers consuming less than the RDA for iron do not show developmental delays should be comforting to parents who are concerned about this critical period of their infants' brain growth. None of the infants were classified as iron deficient based on hematocrit values measured at six months, one year or two years. However, by a stepwise multiple regression method, hematocrit was found to be the strongest predictor of mental development at six months, one year and two years of age. This is felt to be related to the oxygen-carrying capacity of the blood or to a genetic factor. It warrants further investigation.

It is recommended that in further studies a battery of laboratory tests including hemoglobin, ferritin, free erythrocyte proporphyrin, serum iron and TIBC be performed to more exactly quantify the iron status of the infants. Also, it would be advantageous to the researcher, once the iron status is determined, to classify the infants as iron sufficient, iron moderately deplete or iron severely deplete. This classification will aid correlations of the developmental scores with the iron status.

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APPENDICES

Appendix A. Consent Forms

Informed Consent to Participate in a Utah State University Research Project Conducted by Staff From the Department of Nutrition and Food Sciences

Effects of iron status during pregnancy on long term development, behavior and achievement of children

I ____________________________ understand that as a participant in this project I will be required to (1) have a blood sample drawn at the Logan Regional Hospital and be weighed; (2) weigh and record all food, drink and supplements for 3 days; (3) complete a food frequency history during the 32nd week of my pregnancy and have a second blood sample drawn at the Logan Regional Hospital Lab; (4) have a sample of cord blood analyzed for hematological parameters at delivery, and (5) allow researchers to administer developmental and behavioral tests to my infant at 3 mo., 6 mo., 1 year and 2 years of age.

I understand I am to follow my physicians instructions and that no phase of this research is experimental in nature.

In return for my participation I will receive a set of Tupperware measuring cups to keep and a $10 gift certificate in remuneration. In addition, I understand I will have access to all of my individual data including dietary evaluations and blood chemistry data.

I understand I am free to withdraw my participation in this project at any time at the loss of my right to the gift certificate.

I understand there are no expected risks to myself or my infant involved due to my participation in this project.

Any questions relating to the procedures used in this project will be answered by your physician or Deloy Hendricks, Ph.D. 750-2124 or Noreen Schvaneveldt, R.D. 750-2105.

______________________________	______________________________
Participant Signature	Date
______________________________	______________________________
Principal Investigator	Date
______________________________	______________________________
Witness	Date

Appendix B. Dietary History and Record Instruments

6 Month Follow-Up

Subject ______________________ # ____________

Date ______________________

Length ______________ Weight ______________

Head Circumference ______________ HCT ____________

Infant Diet Hx

1. Is your baby breast fed or formula fed? ______________

   If this has changed, when did it occur? ______________

2. If formula fed, indicate which formula is used, and the total amount of milk consumed each day.

   Formula ____________ Total amount/day ____________

   Has the formula changed? ________ Why? ____________

   When? ______________

3. Is your baby fed any food other than formula? ______________

   When were they added to diet?

   a. cereals ____________ d. milk ____________
   b. fruit ____________ e. other ____________
   c. vegetables ____________

Time	Type of Food	Amount

4. Is your baby on a vitamin/mineral supplement? ______________

   Brand ______________

   Dosage ______________

   Time taken ______________

5. If you are breast feeding are you taking vitamin/mineral supplements?

   Brand ______________ Dosage ______________

1 year Follow-Up

Subject ______________________________ # ____________

Date ______________________________

Length ____________________ Weight ______________

Head Circumference ____________________ HCT __________

Diet Hx

1. Is your child receiving breast milk or formula? ______________

2. If formula fed, indicate which formula is used, and the total amount consumed each day. Formula __________ Total amount/day __________

Time	Type of Food	Amount

3. Is your child on a vitamin/mineral supplement? ____________

Brand ______________ Dosage ______________ Time taken ______________

4. Is your child receiving supplemental iron? ________ Brand _________

Dosage _____________ Time taken ________________

5. If child is breast fed, is mother taking vitamin/mineral supplement?

____

2 Year Follow-Up

Subject ______________________ # __________

Date ______________

Length __________ Weight __________

Head Circumference __________

Diet Record

Instructions:

1. List the foods your child eats, including the name and amount, for 3 consecutive days including 2 weekdays and 1 weekend day. Please try to have your child eat what is typical for him or her.

2. Record EVERYTHING your child eats or drinks during each 24 hour period. Remember to write down such items as sugar, juice, milk, butter, margarine, jelly, gravy, mayonnaise, ketchup, mustard, pickles, soft drinks, etc.

3. Describe how the food was prepared and eaten (e.g., boiled, fried or baked) and give a brand name when possible. If a casserole or combination dish is eaten, please include the recipe and indicate what portion of the dish your child consumed (see example).

4. Record the amount of each food and beverage in terms or units such as: cup(s), ounce(s), tablespoons, teaspoons, or slices. For items that cannot be measured in cups, tablespoons or teaspoons (such as banana or meats), please weigh them (see example).

5. Record any vitamin/mineral or other supplements your child takes. Include the brand name, amount and the time taken.

6. Please call me, Mia Owens at 753-5470, if you have any problems or questions.

EXAMPLE

TIME FOOD WAS CONSUMED	TYPE FOOD WITH DESCRIPTION	HOW FOOD WAS PREPARED - FRIED RAW, ETC.	AMOUNT CONSUMED
8:00 a.m.	-frozen unsweetend Welch's grape juice	reconstituted	1/2 cup
	-whole wheat bread-1 1/2 lb. loaf	toasted	1 slice
	-margarine (regular stick)	on toast	1 tsp
	-cream of wheat cereal	boiled	1/4 cup
	-whole milk	on cereal	1/2 cup
	-brown sugar	on cereal	1 tsp
8:30 a.m.	-Tri-Vi-Flor		1 cc
10:00 a.m.	-whole milk	plain	1/2 cup
	-graham crackers	plain	2 squares
	-banana - edible portion only	plain	170 grams
12:30 p.m.	-Campbell's tomato rice soup	with 1 can whole milk	1/2 cup
	-sandwich made with:		
	-white bread 1 lb. loaf	in sandwich	1 slice
	-tuna packed in oil	"	1/8 cup
	-lettuce	"	1 leaf
	-mayonnaise - Kraft imitation	"	2 tsp
	- whole milk	plain	4 oz.
2:30 p.m.	-frozen unsweetened orange juice	reconstituted	1/2 cup
6:00 p.m.	-spaghetti sauce made with:		
	-1 lb. lean hamburger (drained)	simmered	1/2 cup or 1/9 of total recipe
	-2 6 oz. cans tomato paste		
	-1 8 oz can tomato sauce		
	-1/2 tsp garlic powder		
	-1/2 tsp onion powder		
	-spaghetti noodles	boiled	1 cup cooked
	-frozen green beans	boiled	1/2 cup
	-regular stick margarine	on green beans	1 tsp
	-whole milk	plain	1 cup
8:00 p.m.	-orange - edible portion only	plain	180 grams
	-2% milk	plain	1/2 cup

Date ________________

3 Day Intake Record

TIME FOOD WAS CONSUMED	TYPE OF FOOD WITH DESCRIPTION	HOW FOOD WAS PREPARED -	AMOUNT CONSUMED	DO NOT WRITE IN THESE 2 COLUMNS FOOD CODE	GRAMS

Appendix C. Nutrient Intake at
One and Two Years of Age and
Compared with RDA and NFCS 1985

One-Year-Olds Intake Compared
with RDA and National Food
Consumption Survey (1985)

	RDA	Study Mean & SD	NCFS Mean & SD
Energy (Kcals)	1300	1080 ± 330	1250 ± 315
Protein (gm)	23	42 ± 19	47 ± 14
Fat (gm)	-	44 ± 18	44 ± 14
Carbohydrate (gm)	-	130 ± 35	160 ± 43
Cholesterol (mg)	-	208 ± 141	228 ± 119
Calcium (mg)	800	927 ± 432	744 ± 233
Iron (mg)	15	10.3 ± 7.2	9.5 ± 3.6
Magnesium (mg)	150	159.0 ± 62.4	174.5 ± 46.8
Phosphorus (mg)	800	880 ± 398	906 ± 246
Potassium (mg)	-	1705 ± 640	1814 ± 469
Sodium (mg)	-	1170 ± 550	1765 ± 599
Zinc (mg)	10	6.2 ± 3.5	6.9 ± 2.2
Copper (mg)	-	0.6 ± .3	0.7 ± 0.2
Vitamin A *(IU)	2000	5020 ± 2890	3812 ± 2135
Carotene (RE)	-	340 ± 280	208 ± 208
Vitamin E (mg)	5	5.5 ± 4.3	5.8 ± 5.7
Vitamin C (mg)	45	82.2 ± 64.7	86.1 ± 38
Thiamin (mg)	0.7	0.9 ± 0.5	1.0 ± 0.3
Riboflavin (mg)	0.8	1.7 ± .9	1.5 ± 0.4
Niacin (mg)	9	9.0 ± 4.9	12.0 ± 4.2
Vitamin B_6 (mg)	0.9	0.8 ± 0.4	1.2 ± 0.4
Folacin (ug)	100	126 ± 77	169 ± 74.4
Vitamin B_{12}(ug)	2.0	3.4 ± 2.2	3.7 ± 1.4

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*n=32, Does not include vitamin and mineral supplements, however, two infants were supplemented

**1 I.U. of Vitamin A=5 R.E. of Vitamin A

Two-Year-Olds Intake Compared with RDA and National Food Consumption Survey (1985)

	RDA	Study Mean & SD	NCFS Mean & SD
Energy (Kcals)	1300	1120 ± 170	1341 ± 298
Protein (gm)	23	39 ± 9	50.5 ± 13.4
Fat (gm)	-	41 ± 73	46.7 ± 13.8
Carbohydrate (gm)	-	148 ± 24	160 ± 40
Cholesterol (mg)	-	166 ± 87	220 ± 114
Calcium (mg)	800	714 ± 208	794 ± 244
Iron (mg)	15	7.4 ± 1.8	9.3 ± 3.9
Magnesium (mg)	150	148.2 ± 26.1	185.3 ± 47.2
Phosphorus (mg)	800	770 ± 160	973 ± 242
Potassium (mg)	-	1510 ± 370	1923 ± 550
Sodium (mg)	-	1565 ± 490	1964 ± 583
Zinc (mg)	10	5.3 ± 1.3	6.8 ± 2.0
Copper (mg)	-	0.6 ± 0.1	0.8 ± 0.3
Vitamin A *(IU)	2000	3860 ± 3460	4775 ± 3559
Carotene (RE)	-	226 ± 362	247 ± 244
Vitamin E (mg)	5	3.6 ± 1.6	6.0 ± 6.5
Vitamin C (mg)	45	57 ± 38	84.4 ± 47.7
Thiamin (mg)	0.7	0.8 ± 0.2	1.1 ± 0.4
Riboflavin (mg)	0.8	1.3 ± 0.3	1.6 ± 0.5
Niacin (mg)	9	9.2 ± 2.0	12.7 ± 5.0
Vitamin B_6 (mg)	0.9	0.9 ± .2	1.2 ± 0.5
Folacin (ug)	100	135 ± 43	177 ± 81
Vitamin B_{12} (ug)	2.0	2.8 ± 0.7	4.8 ± 5.3

*n=26, Does not include vitamin and mineral supplements, however, 1 infants was supplemented

**1 I.U. of Vitamin A=5 R.E. of Vitamin A