DETERMINANTS OF IRON STATUS IN A HIGH RISK POPULATION OF CANADIAN INFANTS

by

Irene Anne Doyle

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BY

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A thesis submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements of the degree of

MASTER OF SCIENCE

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Irene Anne Doyle

ABSTRACT

THE DETERMINANTS OF IRON STATUS IN A HIGH RISK GROUP OF CANADIAN INFANTS.

The effect of iron fortification of infant formula on iron status was studied in 36 infant and mother pairs. The infants were randomly assigned to iron fortified and non-fortified formula groups. The formula fed infants were selected at random from a Behaviour and Developmental Study at the Children's Clinic at the Health Sciences Centre. A comparison group of 20 breast fed infants were recruited from the Children's Clinic. In addition, the study was designed to investigate non-intervention variables, maternal feeding and childcare beliefs and the degree of social support the mother received.

While iron intake showed no relationship with iron status, calculations of bio-available iron was associated with transferrin saturation. Maternal need for social support showed an association with infant iron status. Maternal beliefs about appropriate weaning foods related to infant ferritin levels.

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DEDICATION

THIS THESIS IS DEDICATED TO MY PARENTS,
MARY (CANNON) DOYLE AND LEO McGRATH DOYLE,
WHO WORKED HARD IN THEIR TIME
TO ENSURE THAT THEIR CHILDREN
WOULD HAVE AN OPPORTUNITY TO ACHIEVE
WHATEVER ACADEMIC QUALIFICATIONS THEY DESIRED.

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CHAPTER 1

1.1 STATEMENT OF PROBLEM

Iron deficiency is one of the most commonly recognized forms of nutritional deficiency in the first two years of life in both the developing and developed world (WHO,1972). Iron is present in all cells in the body and plays a key role in essential biochemical reactions. It is present in hemoglobin, metalloenzymes which are involved in electron transport (cytochromes), and in enzymes for the activation of oxygen (oxygenases) (Hallberg,1982).

Iron deficiency has many serious physiological consequences. Recent studies have shown that a deficiency in iron leads to a reduction in physical work performance (Dallman,1986A). Oski and colleagues have been studying the behavioral effects of iron deficiency. In 1978, Oski and Honig reported that infants with iron deficiency anemia, when treated, had a significant improvement in behavior as measured by the Bayley Mental Index. In 1979, Oski showed that individuals with iron deficiency perform poorly both mentally and physically.

One of the long term effects of iron deficiency is the adverse affect on learning and behaviour. Oski and colleagues (1983) demonstrated that the correction of iron deficiency with parenteral iron was responsible for the improvement of

developmental performance of infants who were tested with the Bayley Mental Development Index, that there was a significant increase in the Mental Development Index scores. The high incidence of iron deficiency and the many clinical, hematological and non-hematological factors associated with iron deficiency, leads one to believe that iron deficiency can become a serious public health issue (Oski,1979).

Iron required for the infant is dependent on growth and its attendant increase in circulating hemoglobin mass is influenced by the rate of growth. The variability in dietary intake and the corresponding response to the intake is broad. Even when infants are given a standard formula to minimize the effect of other factors one can expect that infants will respond in a different manner due to the inter-individual requirements. While the prevalence of iron deficiency anemia among infants is high in both the industrialized and developing world, dietary intake of iron by infants needs to be studied further to understand the effect which diet contributes to iron status. Little is known about the combination of dietary and social factors coupled with maternal feeding and childcare beliefs factors and the contribution they make in the infants' iron status during the first year of life. This study will determine to what extent diet (type, amount, available iron), mothers' perception of infant and feeding care, and infants' environment are related to infant iron status.

CHAPTER 2

2.1 GROWTH IN INFANCY AND ITS EFFECT ON IRON STATUS

The body has three unique mechanisms for maintaining iron balance and preventing the development of iron deficiency: a continuous reutilization of iron from catabolized red blood cells; the presence of ferritin which makes it possible to store iron to meet excessive iron demands; the regulation of the absorption of iron with an increased iron absorption in the presence of iron deficiency and a decreased iron absorption in the state of iron overload. Iron is excreted from the body as unabsorbed iron, sloughing of gastrointestinal tract cell and through the exfoliation of skin (Hallberg,1981A).

The major difference in iron balance between infants or children and adults is the degree of their dependence on dietary iron. The average term infant triples birth weight and almost doubles body iron (Hallberg,1982). Dallman (1986A) compared the dietary iron requirements of the one year old infant to that of the adult male. He calculated that, in a 10 kg one year old infant, dietary iron must provide 30% of the needs for hemoglobin iron turnover as compared to only 5% in the adult male. A six month infant needs to absorb about 0.5- 0.8 mg iron per day to prevent

anemia. The adult male will eat a higher iron concentrated diet and more energy. The year old infant has 270 mg hemoglobin iron in circulation with 2.3 mg hemoglobin turnover per day, whereas the adult male has 2200 mg hemoglobin in circulation with 18 mg hemoglobin turnover per day. Infants are at high risk of iron deficiency because of this high iron requirement, while infants have very little variability in the diet and are unable to consume large volumes of food and generally have few iron rich sources of food in the diet. This indicates the extraordinary requirements of iron in the diet of the infant compared to that of the adult male. In addition, infants are vulnerable in that they may 1) consume diets with low iron content or poor iron availability, 2) be born with decreased iron reserves, 3) have accelerated growth spurts and have excessive demands, or 4) have increased iron losses due to early introduction of whole cows' milk (Wilson,1974). The sum of these factors could explain partly the high occurrence of iron deficiency observed at this age. A critical characteristic of iron nutrition in infancy, as compared to adults, is the greater dependency of the infant on external sources of iron for daily red cell production (Hallberg,1982).

Developmental changes of infancy, show individual variation, including changes in the infants ability to mobilize iron from stores over time (Siimes,1981). In

newborns iron is stored both in red blood cells and in liver, spleen and bone marrow. The high concentration of hemoglobin at birth decreases to the lowest respective value at two months of age due to the increased demands for oxygen (Saarinen and Siimes, 1978). The decrease in hemoglobin concentration initially results in higher tissue iron stores, which are used during the next year to maintain hemoglobin levels. When the infant has an inadequate intake, the needs are covered by drawing from the iron stores. If the mobilization of iron from stores is impaired, then the infant may show signs of iron deficiency. Dallman, Siimes and Stekel (1980) reported that one of the most common causes of iron deficiency in healthy well-nourished infants was inability to mobilize iron from these stores. It is now recognized that iron deficiency, preceding the development of anemia, can result in systemic effects such as developmental delay, cellular immunity, an effect on muscle function and possibly impaired intellectual function (Siimes et al., 1980; Oski et al.,1983; Oski,1979, Dallman et al., 1978).

In the first months of life the demands of iron for growth are supplied by neonatal iron stores and the absorption of food iron plays only a secondary role in maintaining stores (Hallberg,1982). Breast milk, which supplies about 0.25 mg iron per day, assuming an average intake of 800 ml of milk, provides an adequate amount of iron for the majority of term infants during the first six

months of age. (Saarinen and Siimes,1979). Although the iron bio-availability of breast milk is higher than that of cows' milk, breast fed infants require iron supplementation after six months (Siimes et al.,1979). Since milk is the dominant source of energy and the major determinant of iron nutrition during the first year of life, it becomes apparent that iron-rich foods should be introduced into the diet to assist in maintaining a normal level of hemoglobin.

2.2 PREVALENCE OF IRON DEFICIENCY

Iron deficiency is a common nutritional disorder in infants and appears to be more prevalent in lower socio-economic classes. Margo and colleagues (1977), in a study of 344 urban underprivileged children of mixed race in South Africa, found a 23% incidence of iron deficiency anemia with a 53% biochemical evidence of iron deficiency in one year old children. Iron deficiency was defined as a serum iron concentration less than 50 µg/100 ml and transferrin saturation less than 18%. The population was described as being from mixed ethnic origin, with large families who had a weekly income of less than $ 65.00. The infant mortality and childhood mortality rates were 50.8 and 59.6 per 1000 live births, respectively. The median duration of breast feeding was five months and 90% of the children were weaned by 15

months. Solids were introduced usually at 3 months. Foods such as eggs or meat, were used much less frequently than cereals (mostly maize) or vegetables.

In examining the variables, maternal age, education, the presence of the father at home, birth order of the child, family size, income, duration of breast feeding and frequency of meat, green vegetables in the diet of the child, the authors concluded that there was no association positive or negative between family and dietary variables and the nutritional status of the child. This unexpected finding may be due to the homogeneity sample. Nevertheless, the authors point out that subtle family differences not covered by the survey questions may lead to differences in the child's dietary intake.

In contrast, a study of a low socioeconomic group, by Haddy et al. (1974) in the United States, and Ehrhardt (1986) in Britain, showed that social class does have an influence on iron status. Haddy et al., in studying 109 children from low-income families, found a 16% overall incidence of iron deficiency anemia and a 50% incidence of iron deficiency in the under 2 year old. Interviewing 45% of the mothers using a single 24-hour recall of the infants' food intake, they reported that infants with iron deficiency anemia consumed less than 50% of the recommended dietary allowance (RDA). Those infants without anemia consumed approximately 60% of RDA allowance for iron. This result was obtained using a

single 24-hour recall which can provide valid information on usual nutrient intake for groups. (Emmons and Hayes,1973). Similarly, Ehrhardt (1986), in studying children admitted to a British hospital in Bradford, England over a six month period, found an association between socio-economic status and iron deficiency. Ehrhardt reported that 24.6% of the children were anemic, having hemoglobin values below the third percentile of the hospital reference range (Hb<110 g/L), and that these children were predominately from the lower socioeconomic class comprised of Asian ethnic minority. The author further reported that the hospital records had more complete studies for children from poorer sections of society. This was attributed to the fact that physicians recognize the possibility of iron deficiency more readily in poorer children. This latter observation contributed to bias in this sample.

Iron deficiency anemia has been decreasing in some populations in North America. The United States social program WIC (special supplemental food program for Women, Infants and Children) has been shown to contribute to a decline in the prevalence of anemia. The WIC program, which supplies food for those in high risk categories, makes it possible for the infant and mother of lower social class to have adequate iron in the diet.

Miller et al.(1985) in a cross-sectional study, documented the decline in the prevalence of anemia in

children of lower social class from 1973 to 1977. The hematologic status of children from the social program WIC, pre-WIC and post-WIC period was reviewed in this study. Using serum ferritin concentration (<110 g/L), the decrease in prevalence in the 6-month infant went from 20.5 to 0.7%. In the 9-month old child, the decline went from 43.3 to 1.6%. These changes were statistically significant ($P<0.005$).

Oski and colleagues (1983) and Siimes (1981) indicated that improving trends in the prevalence of iron deficiency are due to real improvements in either childhood nutrition or to the intervention of various programs. In studying the effect of the WIC program, Yip et al.(1987A) showed that the incidence of iron deficiency in the United States dropped from 6.2% to 2.7% in a 17 year retrospective study. To determine the magnitude of the decline, another group of researchers along with Yip (1987B), examined hematologic data from six U.S. states that consistently participated in the Centre for Disease Control Pediatric Nutrition Surveillance System from 1975 to 1985. To ensure that the changes were not a function of secular changes in socioeconomic status (SES) among participants enrolled in public nutrition programs, the authors linked birth and nutrition records to study trends among children enrolled in the Tennessee WIC program while controlling for the family SES of these children. They reported that 20% of children in 1975 and 22% in 1984 were in the lowest SES group while 8% in 1975 and 9%

in 1984 were in the highest SES group. This evidence of stability in SES composition over time supports, that any decline in anemia prevalence, is not related to a changing SES composition among WIC-enrolled children but to the WIC program itself.

In a New England setting, Vasquez-Seone et al. (1985) compared the 1971 prevalence of anemia in a neighborhood with its 1984 incidence under similar socioeconomic conditions. The mean hemoglobin concentration in infants went from less than 98 g/L in 1971 to 118 g/L in 1984. In 1971, 23% had hemoglobin less than 98 g/L. In contrast, in 1984 only 1% had hemoglobin less than 98 g/L. These authors also attribute these improvements in iron status to the WIC program. In spite of social programs, the overall nutrition status needs to be improved in the households of the lower social classes if an overall decline in iron deficiency can be expected.

In 1988, data from Alaska in the Mortality Morbidity Weekly Report (MMWR), supported these findings. Alaska is known to be economically poorer than the rest of the United States. It was reported that Alaskan Native children have a high incidence of anemia, approximately 20% of children under 5 years of age. A study of the diets of these children found that the traditional Native Alaskan diet, rich in iron and vitamin C, had been changed to increased consumption of non-native foods that are relatively low in iron content.

In Canada, a retrospective unpublished study at the

Children's Clinic at Health Sciences Centre, Winnipeg, Moffatt and Longstaffe (1986) found that iron deficiency affects up to 59.5% of the infants who have no regular physician and attend a clinic which is situated in the inner core of Winnipeg. The geographical area around the clinic is characterized by single, unemployed, young Native mothers who are supported by social assistance and have one or more children. Although a portion of these women had breast fed their infants, the mothers reported that the milk of choice for both formula-fed and weaned infants was evaporated milk which is known to have low iron content (Canadian Nutrient File,1988).

In contrast, Brault-Dubuc and colleagues (1983) found, in a study of 425 upper middle class Canadian children aged 3 to 36 months in Montreal, that the incidence of anemia was low, approximately 5%. This sample of homogeneous mothers were classified as being from upper-middle class according to scholarity, occupation and family income. The mothers were recruited from prenatal gymnastic classes. The decline in iron deficiency in the middle-class was also found by Yip et al.(1987A). These researchers, in a cross-sectional study, reported a 2.8% prevalence of anemia among 9-23 month old middle-class population. Careful attention was given to select children whose parents had never received social assistance or participated in any of the low-income social programs.

The decline of iron deficiency in the lower social class, while the SES of the families has not improved, may only be credited to social programs. Participating infants, women and children had an opportunity to improve their dietary intakes during a critical time in their lives. While these programs are valuable, the persistent problem of iron deficiency remains a problem in families without financial assistance.

2.3 RELATIONSHIP OF MATERNAL IRON STORES TO INFANT IRON STATUS

Iron intake in the pregnant woman is critical since iron is needed to meet requirements of iron to be incorporated into hemoglobin for disposition in tissues involved in pregnancy, such as uterus and breast, increase in basal losses, the increase in the maternal red cell mass and the requirements of the fetus and placenta and to replace blood loss during delivery. Requirements for iron for a pregnancy can be estimated to be about 1000 mg of which 800 mg are lost from the body permanently and 200 mg are retained and serve as a reservoir of iron when blood volume decreases after delivery (Bothwell et al.,1979). Over the entire period of gestation the amount of iron absorbed daily averages about 3 mg per day.

The role of the mothers' iron stores, as determined by

serum ferritin, in predicting the infants' iron status remains unclear. Rios and colleagues (1975) studied the relationship of maternal iron stores to the iron status of infants. Using serum ferritin determinations in pre-delivery mothers, the researchers found 6 mothers to be iron-depleted (9 ng/ml) while 26 showed higher levels and were regarded as non-iron depleted (34 ng/ml). Serum ferritin was measured in the infant at birth (cord blood), daily in hospital, and $1\frac{1}{2}$, 3, and 6 months of age. Using Student's t-test there was no significant difference in the iron status of infants born of iron-depleted mothers and the iron status of those born to non-iron depleted mothers. There was a non-significant correlation between maternal and infant plasma ferritin in the group of 32 mothers and infants ($r=0.30$; $P>.50$). The authors concluded that the maternal iron stores did not affect the iron status of the infants at birth. This conclusion could change with a larger sample.

In another study on evaluation of iron status in pregnant women and the effect of iron deficiency on the hematopoietic status of newborns, Prual et al.(1988) found a correlation between maternal and newborn hematopoiesis. Iron deficiency was defined as serum ferritin $\leq$ 12µg/L, transferrin saturation <16%, and/or free erythrocyte protoporphyrin >3µg/g Hb. Maternal hematocrit was positively correlated with cord hematocrit ($r= 0.24$, $P<0.05$) and maternal free erythrocyte protoporphyrin was negatively

correlated with cord transferrin saturation ($r=-0.23, P<0.05$) and cord serum ferritin ($r=-0.25, P<0.05$).

From these two studies, it is evident that the role of the maternal iron stores, as determined by serum ferritin, in determining iron status of infants needs further investigation. More research needs to be done in this area before definite inferences can be made.

2.4 IRON BIO-AVAILABILITY AND ABSORPTION

Iron is found in a wide variety of foods in the diet however it is not always readily absorbed. The two forms of dietary iron, with respect to mechanism of absorption, are identified by the terms: heme and non-heme. Heme iron, a ferroprotoporphyrin protein (component of hemoglobin, myoglobin, and cytochromes) is absorbed as an iron-porphyrin complex into the mucosal cells. The assimilation of dietary iron across the intestinal mucosa begins with the absorption of ferrous form in the lumen of the brush borders of the mucosal cells and iron in the ferric form in transport. The largest amounts of iron are absorbed in the duodenal region, but lesser amounts of absorption coincides with the more distal reaches of the intestine.

Regulation of iron transfer from mucosal cells into the capillary circulation of the intestine depends on the iron

status of the individual as well as the rate of erythropoiesis. It has been suggested that apoferrin, a mucosal iron-binding protein, may control the release of iron to the transferrin in the plasma. When iron deficits exist in the body, apoferrin is not synthesized by the mucosal cells, and thus iron can be released to the capillary circulation. If inadequate stores of iron exist, however, apoferrin biosynthesis in mucosal cells is actuated in order to bind iron as ferritin complex (Monsen, 1988; Zapsalis and Beck, 1986; Hallberg,1981A).

The absorption of both heme, to a lesser extent, and non-heme iron is also dependent upon body iron stores (Monsen et al. 1978). Heme iron absorption is not influenced by other food components with the exception of meat and muscle animal tissue. Rates of absorption are inversely related to the quantity of body iron stores.

Hallberg et al. (1979) demonstrated that the absorption of heme iron from a composite meal, not containing meat, was less than half that absorbed if meat were present in the meal. Heme iron absorption also differs from non-heme iron in that if the content of heme iron in a composite meal is less than 5 mg then there is little if any influence on absorption by the subject iron status.

The enhancing effect of animal tissue protein is still not fully understood. Non-heme iron is less well absorbed by humans. It is absorbed in the ferrous form by receptors on

the intestinal mucosal cells and is picked up by a transport protein present on the luminal surface of the cells and converted to ferric form (Bothwell et al.1979). The absorption of non-heme is markedly affected by the iron status of the subject, and by many dietary factors such as animal tissues and ascorbic acid. It has been proposed by Slatkavitz and Clydesdale (1988) that the protein in meat, fish and poultry influences non-heme absorption by the effect of its proportion of constituent amino acids. These amino acids and the associated intermediary products of meat/fish/poultry digestion would chelate with soluble iron and deliver the iron to the gut mucosa. Ascorbic acid is a reducing agent and is capable of oxidizing iron. Ascorbic acid can act as a chelating agent and maintain iron as a soluble complex.

The metabolism of iron can be described as two sequences of biochemical reactions. One internal sequence allows for a continuous reutilization of iron from red blood cells catabolized in the body. Another, external sequence allows for the losses of iron from the body and the absorption of iron from the diet.

The largest proportion of dietary iron in the North American diet occurs in the non-heme form, derived from cereals, vegetables, fruits, eggs and iron used in fortification (Hallberg,1981B). Iron associated with protein designated as heme iron, contributes up to 10 to 15% of total

iron intake in western diets. Dietary heme iron has a higher bio-availability than non-heme iron.

Absorption of non-heme iron is influenced by several factors including the amount of iron in each food item and enhancing factors available in the meal to promote absorption (Monsen et al.,1978). Enhancing factors include ascorbic acid and meat, fish or poultry in a meal which may increase the absorption up to 23%.

Inorganic iron occurs in food primarily in oxidized form as the ferric ion (Fe^{+++}). The reduced form, ferrous iron (Fe^{++}), is more readily absorbed because the receptors have affinity for Fe^{++}. The factors which affect the reduction of iron also affect its absorption. Of particular importance is the pH of the stomach and the upper part of the small intestine. The presence of ascorbic acid increases absorption by enhancing the conversion of ferric to ferrous ion (Kreutler, 1980).

Foods containing phytates, phosphates, and oxalates such as bran, egg yolks, and tea have been found to decrease absorption by as much as 6% (Farkas and leRiche, 1987; Rossander et al.,1979; Hallberg et al.,1977). Polyphenols, such as tannin in tea, bind iron and reduce absorption (Disler et al, 1975). The low absorption of non-heme iron from diets in developing countries and those of lower social class is often due to the limited content of foods stimulating the absorption of the non-heme iron. The

availability of meat, fish or foods rich in ascorbic acid is often quite low in their diets and furthermore, these foods are not choices for many low income families because of the cost (Hallberg and Rossander,1984; Reddy,1987).

Acosta et al.(1984) demonstrated that the differences in iron absorption from meals characteristic of lower class Latin American diets could be attributed to the varying contents of absorption enhancers. The variation in iron absorption from all meals was due, in large part, to variations in the quantities of animal tissue proteins contained in the meals and the amount of vegetable foods containing iron inhibitors. Iron inhibitors are components of foods which combine with other minerals to form a ferric ion compound which is not absorbed in the body.

Hallberg and Rossander (1984), in studying the Latin American diet and ways to improve iron absorption, found that the addition of 75 g of meat to the traditional diet increased the non-heme iron absorption from 0.17 to 0.45 mg an increase of 2.6 times. With the addition of 65 mg ascorbic acid from cauliflower the absorption was increased to 0.58 mg an increase of 3.4 times. The authors also demonstrated that absorption was increased 2.4 times to 0.41 mg with the addition of 50 mg of plain ascorbic acid while the addition of 1 gm of citric acid reduced the absorption to 0.06 mg, a decrease of about one-third.

Studies by Layrisse et al.(1974), Hallberg et al.(1972),

and Cook et al. (1972) demonstrated that the amount of iron potentially available from foods depends not only on the amount of iron supplied but the nature of the iron and the composition of the meal with which it is consumed. An extrinsic Fe^{59} tag model was used to measure absorption of dietary iron.

Monsen and colleagues (1978) demonstrated that absorption of non-heme iron can range from 2% in an iron-replete individual consuming a meal with low iron availability and up to 20% in an individual with no or low iron stores consuming a meal of high iron availability. Viglietti and Skinner (1987) using the 1982 Monsen and Balintfy model, estimated the iron bio-availability in adolescents' meals and snacks. They reported that the bio-availability of non-heme iron was 6.3%. While the heme iron constituted approximately 12% of the total dietary iron, 23% of this was assumed bio-available (Monsen and Balintfy 1982). Raper, Rosenthal and Woteki (1984), evaluated the diets of children one year to two years. The absorption of heme was assumed to be 23% and non-heme to be between 3-8%. They reported that the proportion of total iron calculated as available for children 1 to 2 years of age was 6.5%, 33% of the standard set by the U.S. RDA.

The bio-availability of iron in infant diets is less well understood. Rios and colleagues (1975) reported that ferrous sulfate in milk and soy-based formulas were

associated with a mean iron absorption of 4.2%, while 2.7% of the iron as ferrous sulfate in infant cereals was absorbed. More recently Foman (1987), suggested that absorption of supplemental iron in commercial infant cereals is up to 5%. However, the absorption of iron in the cereal depends on the iron powder particle size and Foman suggested that absorption may be less in many preparations. In response, Johnson and Purvis (1987) of Gerber Products Company, maintain that the electrolytic iron used in fortification is comparable to ferrous sulfate and is an excellent source of iron for infants.

In studying the role of vitamin C in iron absorption, Cook and Monsen (1977) reported that, iron absorption increased with increased vitamin C. More than 50 mg of vitamin C resulted in the mean total iron absorption of 1.94% and in a second group, with an addition of up to 1000 mg, the mean absorption was up to 7.1%. The role of enhancers and inhibitors of iron absorption then becomes important in understanding the etiology of iron deficiency in spite of iron dense foods in the diet.

2.4.1 Effect of breast & cows' milk feeding on iron status

2.4.1.1 Breast milk

Saarinen and Siimes (1979) in a study of healthy

infants, demonstrated that the time of introducing solid foods for infants and the food choice itself may influence iron nutrition more than shown previously. All mothers were encouraged to breast feed as long as possible. Healthy newborn infants were selected to participate in the study and were selected randomly at the time of birth to be allocated to either home-prepared cows' milk formula or a commercial formula . From the total infants series, three study groups emerged, all three of which received breast milk as the only source of milk up to 4 months: 1) a group breast-fed for 6 months and beyond; 2) a group fed with an iron supplemented formula with 11 mg iron/litre; and 3) a group fed a cows' milk home-prepared formula. The infants on breast milk or the cows' milk formula received no supplementary iron. Solid foods were introduced to all infants at 3.5 months according to strict protocol.

The authors reported that the total body iron (TBI), determined from the sum of body storage iron and hemoglobin iron, was at the highest level in the iron-supplemented formula group after the age of four months. The TBI in the breast-fed group increased nearly as well as in the formula group during the first 4 months but stabilized after the introduction of solid foods. When the breast fed group had been weaned at nine months and mixed table food was a major component of the diet, the TBI began to increase. At the time of introduction of solid foods in the non-supplemented

cows' milk group, the TBI increased but at a lower level than for the iron-supplemented group. The hemoglobin was maintained at the expense of the body storage iron in the cows' milk group.

It was reported that, the exceptionally high bio-availability of iron in breast milk decreased noticeably after the introduction of solid foods at four months of age. This study demonstrated that the timing and introduction of solid foods to infants, in particular the breast-fed infant, can have a dramatic influence on the iron status.

In another study of iron absorption, Oski and Landaw (1980) measured the effect of a common baby food on the absorption of iron from breast milk. Five adults participated in this study because of ethical considerations of feeding radioactive iron to infants. These adults were initially fed 1 dL of breast milk that contained added ferrous citrate Fe^{59}, later the same subjects were fed breast milk and one jar of strained pears. The authors found that the absorption of tagged radioiron from breast milk was markedly inhibited when solid foods i.e. pears, were introduced.

Woodruff et al.(1972) in a study of breast milk versus unfortified formula, found that breast-fed infants appear to utilize dietary iron more efficiently. They compared breast feeding with an unfortified formula in infants from birth through to age 9 months who had the same iron intake from

food sources other than milk. Although the overall iron intake was less in the breast fed infants between 3 and 6 months, the utilization of iron was more efficient than the formula group as indicated by the total iron binding capacity (TIBC), ($P<0.05$) . At nine months, half of the infants in each group had biochemical evidence of iron deficiency (transferrin saturation <16%).

The timing and choice of weaning foods are important determinants of infant iron nutrition. In the breast-fed infant, it appears that after the introduction of solid foods the utilization of iron is less efficient while in the formula-fed this is not the case. After the introduction of solid foods in the infant fed an iron fortified formula the iron utilization remains the same. Dietary intake of iron-fortified foods after weaning appears to improve the iron status of the breast-fed and the unfortified formula-fed infants.

2.4.1.2 Cows' milk

Whole cows' milk ingestion has been postulated as a reason for iron deficiency in infants because of the increased possibility of intestinal bleeding. Wilson et al.(1974) demonstrated that the daily ingestion of whole homogenized-pasteurized cows' milk by infants induces gastrointestinal bleeding. In their research, they focused

attention on the heat labile proteins in whole cows' milk and concluded that such related gastrointestinal hemorrhage appears to occur in approximately half of the young iron deficient children who are ingesting a litre or more of homogenized-pasteurized cows' milk daily.

Tunnessen and Oski (1987), in studying the beginning of feeding whole cows' milk to healthy infants of lower middle SES to lower SES at six months of age, found that it was not occult blood that affected iron status. All infants had been fed iron-supplemented cows' milk formula from birth and prior to enrollment in the study. One group was switched to whole cows' milk beginning at six months and the other group continued to receive iron-fortified infant formula. Dietary instruction and reinforcement of supplemental foods were given on a regular basis, both in person and over the telephone by nursing staff.

At age 12 months, it was reported that infants fed cows' milk had significantly lower mean serum ferritin levels (<20 ng/mL) and mean corpuscular volume (<70 fL), higher free erythrocyte protoporphyrin (>35μg/dL) and greater incidence of low hemoglobin (<110 g/L) than did the formula fed infants (24.6 vs. 11.2%). Although supplemental foods were recorded, timing, quantity, or amounts of solid foods, milk or formula ingested was not determined. A comparison of the iron content of formula and whole cows' milk was not recorded. Although the mean hemoglobin values at 12 months were not

statistically different, infants fed cows' milk were twice as likely to have a hemoglobin <110g/L. This supports the undesirable effect of iron status in infants fed whole cows' milk. There was no statistically significant difference in the guaiac-positive stools between the groups. This indicated that it was not occult gastrointestinal blood loss but low iron content of whole cows' milk that was the primary factor responsible for iron inadequacy in the cows' milk group.

The role of fresh cows' milk in iron deficiency was also investigated by Woodruff and colleagues (1972), with three groups of infants: breast-fed followed by prepared formula; prepared formula from birth; and prepared formula replaced by fresh cows' milk at two months of age. They reported that the hemoglobin concentration of children in the cows' milk group at nine and twelve months was statistically significant different from the hemoglobin concentration recorded for the formula fed children ($P<0.05$). Since the calculated iron intakes of the groups were comparable, the results suggested that intestinal bleeding accounted for the poorer iron status in the cows' milk fed group. However the method of collecting the dietary data was not discussed in this paper throwing doubt on the reliability of the dietary data and the conclusions about the role of cows' milk contributing to iron deficiency.

Godard et al.(1987) in Switzerland surveyed 348 healthy one year old infants who had been introduced to whole cows'

milk at or before 3 months or at 6 months. They found no significant difference between either, the distribution of individual hemoglobin and the early introduction of whole cows' milk or the percentage of low hemoglobin (Hb <115 g/L). Limitations in the study included blood testing using capillary blood obtained through finger prick. Although this method is simpler and more comfortable, it decreases the reliability of the test because of the variability in the technique and the limited blood flow.

The conclusion that the addition of whole cows' milk to the diet of the infant would lead to iron deficiency anemia, then remains controversial. More research needs to be done on the effects of cows' milk on infant iron status.

2.5 WEANING PRACTICES

The weaning period in the infant's life is important because it introduces the child to a wider variety of foods as well as foods to promote healthy iron status. Goel (1986) in Scotland, using low serum iron (500 µg/L) as a criterion for iron deficiency, reported that iron deficiency was prevalent in all ethnic groups but most common among the Scots (18.6%) and Asians (16.2%) than among the Chinese (9.8%) and Africans (6.3%). This study did not include a complete diet history. The researchers assumed that Asians

and Chinese people included less meat in their diets than Scots or Africans and relied more on bread, biscuits, eggs, dhal thereby explaining a difference in dietary intake of iron and hence iron deficiency. This study shows that in spite of the availability of iron-rich foods in the United Kingdom, iron deficiency is prevalent in the low income groups. This fact may reflect on the parents' inability to comply with the feeding recommendations for infants and young children and poor data collection.

In a 1987 Canadian study of first generation Chinese children, Chan-Yip and Gray-Donald (1987) studied the prevalence of iron deficiency among Chinese children and its relation to the method of infant feeding. They reported a high incidence of iron deficiency in the initially breast fed infant. The infants, ranging in age from 6 to 36 months, were seen in a pediatric private practice. Of infants who were breast fed for at least two months, 27% were iron deficient while iron deficiency among the formula fed was only 7.0%. The higher incidence of iron deficiency in the breast fed was attributed to the fact that only 27% of the breast fed infants had received an iron-fortified formula at any time, compared with 58% of the formula fed infants. Infant feeding recommendations were given to each mother and no attempt was made to change the feeding pattern of children who had been fed traditional Chinese weaning food.

The weaning habits and practices, ie. conventional

weaning food beginning at 4 months, appear to be influential in the incidence of iron deficiency. The traditional Chinese weaning food is reported to have low iron bio-availability (Hallberg,1982: Hallberg et al.,1977). The iron deficiency was related to the feeding method although no attempt was made to record the amount or quality of the infants' diet, therefore, no correlation between types and quantities of foods was attempted.

2.5.1 Weaning and iron status in lower social classes

The practice of weaning varies widely among cultures when it is initiated and/or terminated, as well as variety, quantity and quality of the weaning foods that is provided. The choice of weaning foods by the mother or caregiver among the lower economic classes may be a primary cause of iron deficiency (Reddy,1987; Underwood,1985). Reddy (1987) postulated that much of the weaning food used in lower SES households is usually only a slightly modified version of the common diet At this early age the child may not be able to consume adequate amounts of food unless fed at frequent intervals. Infrequent feeding does not enable the infant to consume an adequate volume, hence energy and iron intake will be inadequate. The iron sources which are best absorbed ie. animal tissue, many not be a choice for these families due to cost. It has been shown that the replacement of iron rich

foods with tea, milk, dairy products and vegetables will limit the amount of iron that is absorbed (Farkas and leRiche, 1987; Charlton and Bothwell, 1983; Hallberg, 1981A). In contrast, the presence of ascorbic acid with the meat will enhance the absorption of iron from the entire meal (Monsen and Balintfy,1982; Monsen et al.,1978; Dallman, Siimes and Stekel,1980).

Most often, when breast feeding is prolonged, the practice is to provide some complementary food from the early post delivery months onward. However, among some poor societies and in deprived environments, this food may be limited and monotonous in flavour and texture. This may act synergistically with the consequences of a chronically depressed appetite and to limit acceptance of additional food in quantity and variety at the time when this becomes critical for meeting nutritional needs of the growing infant (Underwood,1985).

The middle to upper class families will more often feed foods that are prepared at home or will purchase processed weaning foods which includes meat. The middle to upper class more often are educated and have better access to the health care system. They make use of a wider selection of materials on infant feeding and nutrition information.

The introduction of an iron-enriched infant cereal to the weaning diet contributes to a high intake of iron up to one year of age. Chan-Yip and Gray-Donald (1987) found, that

after the first year of life, the number of families feeding iron fortified cereals dropped by 50% and the dietary iron was not replaced. Although the intake of the cereal is usually low after first year of the child's life, the introduction of foods high in heme iron usually compensates for the loss of dietary iron intake.

2.6 STANDARDS FOR RESEARCH

2.6.1 Iron status

Reliable indicators of iron status are essential for assessing the magnitude and distribution of iron deficiency in populations as well as for developing effective public health measures (Cook and Reusser,1983; Stare,1979). Iron deficiency anemia has been described by Dallman as a state in which there are no available iron stores and an insufficient supply of iron to the bone marrow erythron and to other tissues. Anemia, as defined by hemoglobin levels, is a late manifestation of iron deficiency. Latent stages can be determined by transferrin saturation and serum ferritin (Dallman,1977). It has been demonstrated that the use of a combination of several indicators, predictive of different levels of iron depletion, improves the specificity of the diagnosis of iron deficiency (Cook and Finch,1979).

The iron status of the infant changes rapidly in the

first year of life. Between birth and four months of age, there is little change in total body iron and there is little need for exogenous iron. Abundant neonatal iron stores help to provide for synthesis of hemoglobin and myoglobin as well as metalloenzymes. Hemoglobin iron increases only slightly, despite a substantial rise in blood volume, because the concentration of hemoglobin declines from a mean of 170 µg/L at birth to 125 µg/L. At about 4 months of age, there is a gradual shift from an abundance of iron to the marginal iron reserves because of the demand for transport of oxygen as well as growth. Large amounts of iron must be assimilated during the remainder of infancy to allow for a rapid increase in total body iron (Dallman,1986B). Infants not breast fed should have an iron intake of approximately 1 mg/kg. Later when the iron stores are depleted the hemoglobin will decrease since the infant depends on dietary iron to maintain normal iron status.

One definition of iron deficiency uses a serum iron value less than 500 µg/L, or a hemoglobin level below 110 g/dL in the under six year old (WHO, 1972). The WHO standards cover a six year range, hence it is possible that the use of this standard may overestimate the prevalence of anemia in young children and underestimate anemia in older children. Applying any one standard across ethnic groups poses problems because it is known that hemoglobin levels vary with race (Garn et al.,1981; Garn et al.,1975; Kraemer

et al.,1975; Owen et al.,1975) and age (Yip et al, 1984).

Although one can define anemia in terms of hemoglobin, which is a good estimator of anemia, a more precise definition can be achieved by using other measures of iron status such as serum ferritin, transferrin saturation, mean corpuscular volume, and free erythrocyte protoporphyrin. Using these other indicators along with hemoglobin will eliminate many false positives and false negatives thereby increasing the possibility of detecting iron deficiency in subjects.

In addition to hemoglobin levels, indicators of iron deficiency are: low serum ferritin; decrease in transferrin saturation; decrease in mean corpuscular volume; and an increase in free erythrocyte protoporphyrin. Serum ferritin concentration, which is a indicator of iron stores, rather than either hemoglobin concentration or percent transferrin saturation, is the most sensitive index of the earliest stages of iron deficiency, defined as a reduction of iron stores (Valberg et al.1976; Lipschitz et al.,1974). Thus it becomes apparent that one indicator is inadequate to determine to what extent an individual is iron deficient. A combination of laboratory tests is more accurate in diagnosing anemia and iron deficiency (Yip et al.,1984; Cook and Finch, 1979; Valberg et al.,1976).

2.6.2 Social needs and social support

Socioeconomic position is one of the risk factors to poor health (Haan et al.(1987). People in low SES groups experience higher incidence, higher mortality rates and poorer survival rates for most chronic diseases (Haan et al.,1987; Walker and Walker,1986). Poor nutrition and nutritional status explain the increased incidence of noninfectious diseases and general poor health among low socioeconomic sectors of society. Population growth in SES disadvantaged groups, i.e. single parents and natives, is increasing at a faster rate than the general population and their economic position is worsening (Social Planning Council,1989). Social needs are defined as environmental conditions or behaviours, statements of human problems, of gaps or discrepancies between what is and what should be, which are at odds with what one desires them to be (Social Planning Council,1987).

Maternal and child welfare has been a concern for many years (Williams et al.1987; Sevenhuysen,1986). While nutrition remains a component of child welfare, it is clear that its influence does not fully explain the overall nutritional status of the child. The influence of other factors such as education attained by the mother, age structure of the family, and SES have been described while

little is known about social support system for mothers. These issues have prompted interest in the identification of social and environmental factors that could influence health status. Researchers have studied the role of social support of the individual in influencing general health status (Cassel,1976). Cassel (1976) has proposed that lack of social need, as one of many social-psychological variables, could help explain a generalized susceptibility to disease.

2.6.2.1 Defining social support

The role of social support in influencing health status has been described in a number of ways (Jacobson,1986; Thoits,1982; Nuckolls et al.,1972). The varying opinions and definitions have led to a separation of perceived support and received support. Turner (1983) defined perceived support as a perception that one is loved and esteemed by others and knowledge that one is part of a set of obligations, while received support is seen as the actual transfer of advice, aid and affect through interpersonal networks.

A clear understanding of social support requires that it be distinguished from social networks. Social networks describe interpersonal relationships, the relative strengths and function of these relationships to the individual. These relationships provide the mechanisms through which social

support is provided. Social networks have structured features that can assist in changing or enhancing the health and functioning of an entire population (Gottlieb,1983). Social support, on the other hand, is seen as the assistance an individual receives in dealing with conflicts and needs and the perception that support could be available if it was needed (Cohen et al.,1985; Sarason et al.,1983; Procidano and Heller,1983). It has been suggested that a perception of being cared for, in itself, promotes health (Lynch,1977; Cobb,1976), whether or not the perception is accurate. It is also recognized that the perception of being supported is not necessarily determined primarily by the environmental support resources that are actually available from one's social network.

For this study then, definitions proposed by Cobb (1976) and Lynch (1977) have been combined and adapted to include both perceived and received support. Social support is defined as information and/or resources that are given to the individual from individuals, groups, or the larger community that leads one to believe that one is cared for, loved, esteemed and valued, and belongs to a network of communication and mutual obligation (Lynch,1977;Cobb,1976). The focus of this definition is on the importance of perceived support and the consequences of interaction in human relationships and not isolation. This is consistent with the belief that it is the quality of support and

perception of support available that is the crucial element (Jacobson,1986). This requires that information on the subjective appraisal of the support available from the individual's social environment should be collected. The social context in which an individual functions represents an additional component of social support. This includes those people who are either a potential or actual source of support (Jacobson,1986).

Social network analysis, as suggested by Gottlieb (1983), may be applied to provide a quantitative description of the structural and functional support of one's social environment. An alternative approach is to use indices that reflect the availability of social resources, access to support, and of participation in community organizations. These measures provide information concerning the extent to which individuals are linked to significant people and have opportunities to interact which might foster the expression of social support (Barrera,1981). The mothers' perception (subjective) of their social support and needs should be collected as well as the researchers' (objective) view of the information on social support and needs as perceived by the mothers. Both should be included separately in measures of social support.

2.6.2.2 Social support and health

A relationship between social support and health has been described (Gottlieb,1983; Cobb,1976). Gottlieb,(1983) hypothesised that social support may directly influence an individual's health, either through shielding one from exposure to certain kinds of stressors or enhancing health and morale in general and thus serving a health promotive function (Gottlieb,1984). Others have investigated this hypothesis (Lin et al.,1985; Dressler,1985).

The stress modifying effects of social support were examined by Lin and colleagues (1985). A longitudinal study was carried out on the buffering effects of social support or stress in the individual as a result of the most important and undesirable life event experienced. Male and female adults from age 18 to 70 years participated over a 4 year period. Social interaction between the individual with persons with whom he/she had strong ties were recorded during and subsequent to the event. Depressive symptoms were recorded using the Centre for Epidemiologic Studies Depression Scale (DES-D) which is a simple summated score of 20 items related to depression reported for the week prior to the survey (Markush and Favero,1974; Radloff,1977). Initially 1,091 self-selected subjects were interviewed and 871 were subsequently reinterviewed to determine the effect of social support.

The strength of ties was measured in terms of both the role relationships involved and the dimensions of the interactions. Following the identification of the most important event, the subject was asked if anyone had helped during or after the event and what the role relationship was between the subject and the helper. Strength of ties was represented by acquaintances or helping professionals, close friends, other relatives, or spouse/lover. The dimensions of interactions were determined by using a series of questions on the frequency and intensity of the interactions as follows: 1) number of years known; 2) frequency of contact in the last 6 months; 3) frequency of talking about problems to this person; 4) frequency of this person talking about his/her problems to subject; 5) ease of contact with the person; 6) talking freely to the person; 7) importance of a person to subject; and 8) how much the person helped during the event. The researchers reported that help from stronger ties were generally associated with lower levels of depression. When the event was bad or uncertain and was accompanied by help from a spouse or relative the depression level mean was lower than it was when the event was accompanied by help from a close friend, an acquaintance or helping professional. This finding is evidence of the buffering effect of social support as indexed by the strength of the role relationship of the subject to the person providing help.

An effect of extended family social support on health was reported by Dressler (1985), in which 285 households of a major black community in a U.S. southern city participated. The self-selected respondents were comparable to the total population on demographic characteristics of 1980 census.

Social support was operationalized as "extended kin network" which was quantified as the simple sum of the number of siblings, aunts, uncles, parents, adult children, grandparents, nieces and nephews and half-siblings living within the city . "Extended kin support", a subset of all extended kin, was defined as those who were perceived as supportive to the subject. "Non-kin support" was identified as membership in social and political organizations, participating in church activities, employment outside the home, and reported interaction with friends.

Two measures of stressors were used: " economic stressors" included chronic economic problems and "stressful life events" included death of spouse or child, divorce. The dependent variable was depression using a checklist to assess common symptoms of depression.

The researcher reported that extended kin support was significantly related to fewer symptoms of depression ($P<0.05$). While this study used measures of kin support and network that explicitly distinguished between the quality of support and quantitative aspects of support and only in

relation to depressive symptoms. The effects of other chronic stressors may also be mitigated by social support.

2.6.3 Nutrient intake assessment

2.6.3.1 Dietary data

Dietary data collection in the free-living population poses challenges to accuracy and reliability. The logistics of gathering data, such as transportation and subject mobility, further leads to frustrations and complications. One of the most important reasons for complications in collections of dietary data is the lack of a precise instrument that can be used.

Various methodologies have been employed to circumvent this problem. In this situation, reproducibility of a method might provide a measure of reliability. Reproducibility is defined as referring to variability of a measurement on the same subject under the same conditions (Burema et al. 1988; Reshef and Epstein,1972). While this is impractical on the same day in dietary intake data, repeated measurements on the same subject on consecutive days will necessarily relate to usual intake on different days.

Consequently, to assess reproducibility, two or more measurements relating to periods in time, although different, are as similar as possible.

Reshef and Epstein (1972) studied the reliability of a dietary questionnaire with 60 subjects, male and female. They grouped the subjects according to sex and country of birth. All subjects were interviewed twice at home by the same specialized nutritionist who conducted the first interview. The reliability of the questionnaire in estimating the usual consumption of particular foods did not vary in sex and country of birth groups. The mean values for energy, carbohydrate, protein and fat were not significantly different in the two interviews. It was noted that there was an increase in variability in the diets but this variability of diet did not affect the reliability of the data.

In dietary intake data collection, questions must be precisely formulated with careful attention to the education and experience of the subject. It is recognized and documented that information from dietary recalls involves a good deal of error. Error is defined as any component of the population variance which is not due to actual differences between individuals (Gordon et al., 1984). These include both the error and variation due to changes in daily eating patterns, inaccuracy in recall or the evaluation of what and how much was eaten.

Burema et al. (1988) explains that sources of error in

data collection may be due to the discrepancy between what the investigator wishes to estimate and what the technique actually estimates. Error may also be due to systematic error in data collection and random error due to instructions to subject, wording of the questionnaire, ability of the respondent, skill of the interviewer and the research setting.

Todd et al. (1983) reported that a single recall did not give an accurate assessment of what was eaten when it was compared to the weighed record. However, Lechtig et al.(1976) suggests that a repeated 24-hour recall can accurately classify the dietary intake of an individual for all nutrients.

In spite of the limitations in collecting dietary data, one of the most widely used approaches to collecting dietary information is the repeated 24-hour dietary recall method. The recall method of assessing dietary intake has been recognized as being practical, economical, logistically simple, valid and reliable (Karvetti and Knuts,1981; Beaton et al. 1979). Error related to data collection of infants' dietary intake may be due to estimations of food intake by the person being interviewed who may not have been the sole provider for the infant.

2.6.3.1.1 Analysis of dietary data

Individual nutrients, such as iron, are strongly correlated with energy intake. Since the concentration of iron is closely identified with the energy intake it is useful to employ a measure of nutrient intake that is independent of total energy intake. Willett and Stampfer (1986) developed a calorie-adjusted nutrient intake approach whereby the residuals of the regression model of absolute nutrient intake served as the dependent variable and total calorie intake as independent variable are used in a regression equation to produce an index of nutrient intake independent of energy. The residuals are then related to energy-adjusted nutrient intakes of individuals which are uncorrelated with energy intake. Their use will overcome the problem of high collinearity observed with nutrient and energy intakes.

Another method of estimating adequacy of intake for individuals was used by Czajka-Nairns and colleagues (1978). This method compares the dietary data with an index that was calculated, taking into consideration the individual requirements. The index was calculated by dividing absolute nutrient intake per subject by kilogram body weight. In calculating the daily iron ingested per kilogram body weight they found that the iron deficient child with anemia consumed less iron daily per kilogram than did the iron replete child. The reason for choosing this adjustment was not reported. It is assumed that body weight is an indicator of the weight of

metabolically active tissue iron including tissue involved in iron metabolism. The amount for iron turnover is related to the speed of metabolism and the weight of tissue. Intake of iron per kilogram body weight is related, in part, to the rate of erythropoiesis as well as to blood volume and therefore the demand for iron.

2.6.4 Feeding beliefs

The decision of the mother to either breast or formula feed an infant and the subsequent introduction of solid food influences the iron status of the infant. The introduction of weaning foods and the type of food to be given depends on factors such as availability of food, socioeconomic conditions and family food habits (Reddy,1987). In addition, her understanding of when the infant is expected to receive additional foods would be helpful in predicting the possible iron status of the infant.

The social circumstances of the mother may determine her ability to provide optimum nutrition to her infant. Levine et al. (1985), in studying mother-infant interactions in adolescent mothers found that adolescent mothers, with less education and support, represented a high risk subgroup of adolescent mothers who provide less optimum care-giving

environments for their infants. These mothers talked less to their infants and demonstrated tasks less often. Elster et al. (1983) in a review of the literature on adolescent mothers, found that these mothers are faced with excessive stress, have inadequate social support networks, lack knowledge of child development, are developmentally immature and possess inappropriate child-rearing attitudes.

The mothers' choice of weaning foods, timing of introducing solid foods may be related to their ability to cope with child-care and feeding. An understanding of these weaning and childcare beliefs may be related to iron status of the infant and a questionnaire on these beliefs would be helpful in understanding the determinants of iron deficiency.

2.7 GROWTH

Growth indicates general health performance and growth at predicted rates suggests the nutritional environment is adequate for normal functioning. Growth could therefore, be used as an additional indicator of nutritional status. Growth during infancy is characterized by a high velocity. The maximum rate occurs in the first year of life, during which a term infant triples its birth weight (Stekel,1984). Growth velocity is calculated from two anthropometric measurements from specific time points. Growth velocity

values are small compared with distance values and reference data must be obtained meticulously (Brandt,1980).

Anthropometric status and rate of growth during childhood have been proposed as sensitive indicators of environmental influences on the child (Susanne,1980). The relationship between SES and the prevalence of severe nutritional problems is evident in underdeveloped countries (Rae,1971, Bogin and MacVean,1978). Infant growth may be associated with factors, such as genetics, prenatal history, birth size, infections during infancy and nutrition factors. Hoffmans and colleagues (1988) studied 161 well nourished infants of normal length during the first four months of life and reported that birth weight was inversely related to growth velocity. The infants of smoking mothers showed a growth velocity higher than those infants of non-smoking mothers ($P<0.05$). The study also showed a significant relationship between feeding practice and the introduction of weaning foods both of which influenced growth velocity.

Feeding practice and type of milk have been postulated as having an influence on growth velocity. Ahn and MacLean (1980) investigated the adequacy of breast milk on the physical growth of 96 infants. The average duration of exclusive breast feeding was seven months. They reported that the weight and length curves of the infants during the period of exclusive breast feeding remained above the 50th percentile of the National Centre for Health Statistics

(NCHS) population through to at least the sixth month. This growth was reduced to the 25th percentile through the ninth and 10th months of life. There was no significant difference between weight and length curves of infants who had been exclusively breast fed for six months of age and those of infants who had been exclusively breast fed for more than six months. The parents in this study group were of a higher SES and were enthusiastic about prolonged breast feeding and following the study protocol.

In contrast, Duncan and co-workers (1984), in a study of 33 term infants who were exclusively breast fed for six months, showed a significantly slower rate of growth when compared to data from the NCHS. By six months the mean weight and length were equivalent to values below the 50th percentile of the NCHS. While most maintained rates of growth that placed them within two standard deviations of the mean for age, 48% lost 20 or more percentiles in weight between birth and six months. While this study may suggest that breast fed infants lack adequate nutrition for growth it is important to note that limitations in the study were a lack of a control group of exclusively formula fed infants and the lack of information on demographic characteristics on the families. Furthermore the NCHS data is based primarily on growth in formula fed infants and reflects the feeding practices at the time of the Fels study in the 1940s.

Harrison et al.(1987) compared the growth and

composition of growth of 111 normal term infants who were exclusively breast fed and fed 1 of 2 formulas that differed primarily in whey -to- casein protein ratio. These researchers reported that the mean weights of male and female infants in each feeding group did not differ and were between the 25th and 75th percentiles of the NCHS growth standards at every measurement age. Daily weight gains were not different between the groups. Mean lengths remained at their respective NCHS percentiles during the 16-week study period. In addition, they detected no important differences in the rate of growth of term infants fed either casein-predominant formula or whey-predominant formula or were breast fed.

It is reasonable then to expect that the velocity of growth of infants either formula or breast fed would not be significantly different within the same SES and cultural group.

CHAPTER 3

3.1 STUDY PROTOCOL

3.1.1 Purpose of research

The etiology of low iron status in apparently healthy infants of families in low socioeconomic groups is unclear. The possibility that maternal feeding practices and childcare beliefs may be associated with the low nutritional intake of iron and thereby influence the infants' iron status requires investigation. Similarly, the amount of available iron in the diet may be related to iron status and needs further study. Social support may be one determinant of maternal feeding and childcare beliefs, which would indirectly affect the iron status of the infant. Similarly, the dietary intake of the mother may be an indicator of the overall nutrition environment of the infant and show a relationship with iron status. This study was designed to determine the relationships between these nutritional or social factors and iron status of the infant in a low socioeconomic environment.

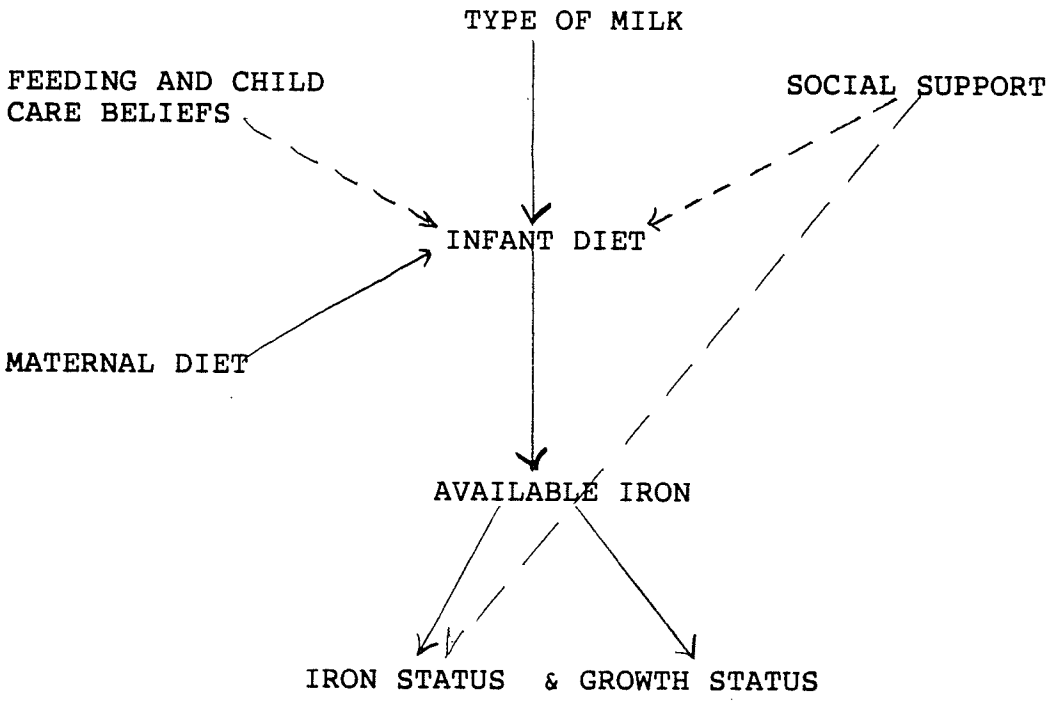
3.1.2 Research questions

This study was designed to answer the following questions:

1. Is the intake of available iron related to the iron status of the infant?
2. Are the feeding and childcare beliefs of the mother at birth related to the iron intake of the infant?
3. Does social support influence the iron status of the infant?

3.1.3 Design

The conceptual framework for the study is illustrated in Figure 1.



Relationships are noted by solid lines (direct effect) and broken lines (indirect effect).

3.1.4 Data collection procedure

Figure 3 summarizes the procedure for data collection at data collection series one and two.

Figure 2.

DATA COLLECTION PROCEDURES

DATE OF ENROLLMENT

RECORD 1

Day 1	Consent of participation Feeding and childcare questionnaire Day 1 Infant 24 hour dietary recall Maternal 24 hour dietary recall Blood drawn for analysis Anthropometric measures
Day 2	Social support needs questionnaire Day 2 Infant 24 hour dietary recall Maternal 24 hour dietary recall

RECORD 2

Day 1	Day 1 24 hour dietary recall Maternal 24 hour dietary recall Blood drawn for analysis Anthropometric measures
Day 2	Day 2 Infant 24 hour dietary recall Maternal 24 hour dietary recall

Day 1 and Day 2 were consecutive days

Subjects in this study were either breast fed or formula fed. Breast fed was operationalized as those infants whose mother decided at birth to breast feed and breast fed for at least 2 months. Formula fed was operationalized as those infants whose mothers chose to formula feed at birth or had weaned the infant from the breast by the time of a neonatal clinic appointment before 2 months of age. Subjects who were formula fed were randomly allocated to either iron-fortified or non-fortified formula through a double-blind procedure.

Data collection series was operationalized as first series of data collections on day one and day two when the infant was approximately six months of age. The second series coincided with the 12 month birthdate of the infant. Data was again collected on two consecutive days, day one and day two.

3.1.5 Hypothesis

Hypotheses were formulated regarding the relationships among dietary iron intake, feeding and childcare beliefs, social support, and the iron status of the infant.

1. Dietary iron intake of the infant is positively related

to the iron status of the infant.

2. Fortification of an infant formula with iron improves the iron status of the infant.

3. There is no difference in the growth velocity between those infants whose diets contained iron fortified formula and those whose diets contained an non-fortified formula or were breast fed and weaned to a milk of the mother's choice.

4. Maternal feeding and childcare belief scores are inversely related to the iron intake of the infant.

5. Feeding beliefs and social support needs scores of the mother can predict high and low iron status in the infant.

6. The maternal social support needs score is positively related to the iron status of the infant.

3.1.6 Variables

3.1.6.1 Dependent variables

Dependent variables were;

1) iron status of the infant as determined by hemoglobin (Hb g/L), serum iron (SIμmol/L), serum ferritin (SF μg/L), mean corpuscular volume (MCV fL), total iron binding capacity (TIBC μmol/L), transferrin saturation (TS %), and free erythrocyte protoporphyrin (FEP mg/L) and

2) growth of infant as determined by length (cm) and weight

(kg).

3.1.6.2 Independent variables

Independent variables were maternal diet, type of milk, type of food, feeding and childcare beliefs, maternal ferritin and social support.

Age of infant was operationalized as the time of first record and second record minus the date of birth.

Maternal diet was operationalized as the nutritional intake of the mother at the time of the first and second series of dietary recalls. The intakes were calculated for energy, iron, vitamin C, protein, fat, and carbohydrate.

Type of milk was operationalized as formula- either iron fortified or non-fortified, and breast milk.

Infant diet was operationalized as the quality and quantity of food consumed by the infant at the time of first and second series of dietary recalls. The intakes were analyzed for energy, available iron, vitamin C, protein, fat and carbohydrate.

Feeding and childcare belief was operationalized as 8 initial scores and 3 combinations of these thus making a total of 11 scores. The three additional scores describe the mother's perception of the quality of the diet for the infant; the mother's ability to respond to the infant's signals of hunger; and the mother's belief about coping with

any of the most common disorders of infancy. The scores ranged from 1, (optimal); 2, (adequate); 3, (poor). (Appendix 1)

Social support- social support was operationalized as one score which describes the extent of support the mother perceives from information and/or resources offered to her by family, friends, agencies and services. The perception that she is cared for, loved, esteemed and valued and that she belongs to a network of communication and mutual obligation was recorded. The scores ranged from 1, (complete); 2, (adequate); 3, (poor); and 4) (very poor). (Appendix 2)

Maternal risk score was operationalized as one score which was completed on admission to hospital for delivery of the infant. This score which was obtained from the Medical Record, categorized the mother in terms of low risk (0-2); high risk (3-6); and extreme risk ($\geq$7) (Morrison and Olsen, 1979). This score has been effective in predicting the successful outcome of pregnancy and could be effective in predicting the iron status of the infant.

The study was carried out with the approval of the Ethics committees of both the Faculty of Human Ecology and the Faculty of Medicine of the University of Manitoba. (Appendices 3 and 4) All mothers or caregivers signed a consent form for all the procedures undertaken (Appendices 5A and 5B).

CHAPTER 4

4.1 METHODOLOGY

4.1.1 Subjects

All subjects were infant/mother pairs from the inner core of Winnipeg and classified as University of Manitoba Service Patients and/or infants born to women in a non-referred category at the Women's Centre of the Health Sciences Centre (HSC) and/or attend Children's Clinic at the HSC. Non-referred category refers to mothers who have not been followed exclusively by one physician during this pregnancy.

The criterion for selection of infants was that there were no chromosomal anomalies; an Apgar score greater than 5 at 5 minutes; greater than 34 weeks gestation; the mothers classified as non-referred patients. The inner core of the city is characterized by high incidence of poverty, and a number of other social factors such as single, Native mothers who have immigrated to the city from reserves outside Winnipeg (Social Planning Council, Winnipeg,1987).

If, at the time of birth, the mother decided to formula feed, the infant and mother pair was enrolled in a study, entitled "Behavioral and Developmental Effects of Iron Deficiency in Infancy" [BDS] conducted by the Department of

Community Health Sciences. At this time, the mother was approached by the coordinator of the study to inform her of the details of the study including the protocol of feeding, developmental assessments, iron status determinations as well as home assessment appointment. Written informed consent was obtained. (Appendix 6).

The mother was given one of two types of formula provided by Mead Johnson [1], a protocol developed by the Behavioral and Developmental Study group. All formula was concentrate and labelled in the same manner. The allocation to iron fortified or non-fortified formula was double-blind, achieved through random selection from pre-prepared sealed. The iron fortified formula contained 1.27 mg iron/100 ml as ferrous sulfate while the non-fortified formula contained 0.11 mg iron per 100/ml as ferrous sulfate.

The selection of subjects for this study were from two populations. One population was from a study in progress at the Health Sciences Centre, Department of Community Health Sciences. This study was designed to study the effects of iron deficiency on infant behaviour and development. Infants for this study were recruited from the non-referred patients at the Women's Centre at Health Sciences Centre. The Behavioral and Developmental Study group provided a random sample of 36 formula fed infants. Names and addresses of subjects were obtained from the coordinator of the Behaviour

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[1]. Mead Johnson Canada, Ottawa, Ontario.

and Developmental Study. Subjects were introduced to the researcher by the coordinator and all mother/caregivers signed a informed consent. The other population of breast fed infant/mother pairs were recruited through the Children's Clinic at the Health Sciences Centre. Names and addresses were obtained from nurses in the Clinic. The period of data collection for the Behavioral and Developmental Study group was begun approximately June, 1988 and will continue until July,1992. Approximately 8-10 infant/mother pairs were eligible to participate per month with refusals accounting for 5% of these mother/infant pairs. Refusals includes those who did not wish to participate for personal reasons. The dropout rate of the enrolled subjects was approximately 15% at the time of data collection for the BDS study. The dropouts included those who moved from their homes without leaving a forwarding address and those who did not follow the protocol including those who missed scheduled appointments. At the time of data collection for this study, 45 subjects met the age criteria and were between six to 9 months of age.

Figure 3 summarizes the period of data collection.

Figure 3

PERIOD OF DATA COLLECTION

[Feb.1,1989 to September 30,1989]

SUBJECTS

BDS[2]		BREAST-FED	
eligible	=45	eligible	= 31
refusals/[3] unavailable	= 9 (20%)	refusals/ unavailable	= 11 (35.5%)
enrolled	=36 (80%)	enrolled	= 20 (64.5%)
dropout	= 1 (2.7%)	dropout	= 2 (6.5%)

SUMMARY

TOTAL NUMBER ELIGIBLE FROM POPULATION {BDS AND BREAST FED}	=96	
ENROLLED	=56	(58.3%)
DROPOUT	= 3	(5.35%)

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[2] BDS refers to the Behaviour and Developmental Sample from which the formula fed infants were recruited.

[3]. refusals/unavailable includes the number who did not wish to participate, those who moved from their homes without leaving a forwarding address, and those who were unavailable for a stated appointment.

Three groups of infants were studied. Group 1 consisted of those infants who consumed a diet of iron fortified formula; group 2 incorporated those infants fed a non-fortified formula and group 3 comprised those infants who were initially breast fed and weaned to a formula/milk of the mother's choice.

4.1.2 Enrollment

All names of potential formula fed subjects were made known to the researcher by the Coordinator of the Behavioral and Developmental study group. The enrollment of breast fed subjects was done in a similar manner. All names of potential breast fed subjects were made known to the researcher by nurses from Women's Centre, Neonatal and Medical Clinics of Childrens' Hospital. Subjects were enrolled at birth and between six and up to nine months. The researcher met the mother and infant of the Behaviour and Developmental Study group when the infant had the first or second developmental assessment at 6 or 9 months. The breast fed subjects were enrolled at birth, and between six and up to nine months due to the restraints on data collection time. The mother and infant were enrolled when the infant attended a neonatal appointment at the Children's clinic or shortly thereafter.

The mothers received compensation for participation. The mothers of subjects in Behaviour and Developmental Study received formula free of charge. The breast fed subjects received a gift of a hand-made baby sweater at the time of enrollment and a gift on the occasion of the first birthday for the subjects from whom 12 month data were collected. All subjects were given taxi fares, when warranted, to attend scheduled appointments.

4.1.3 Maternal and infant diet

The 24-hour dietary recall method was chosen to provide a quantitative estimate of the mother's and infant's nutrient intake on 2 consecutive days. Since the infant diet is expected to have a small variation form day to day hence fewer repetitions of daily intake would be required to measure daily intake. It was assumed that two consecutive day intake were adequate to estimate usual intake. In addition, it was felt that the study population would provide only two days of intake data. To avoid multiple visits to the home and disruption of the family routine, the researcher coordinated the first visit with a clinic visit to discuss the study, obtain written consent and record the first of 2 consecutive 24-hour dietary intakes. (Appendix 7) Since the subject population was accustomed to many care providers collecting data on various aspects of their lives, care was

taken to assist the mother in understanding the relationship of diet to the infants' well-being.

Dietary information was collected when the infant was between 6 to 9 months for the 1st series of data collection and 12 months of age for those subjects who had reached their first birthday by September 30,1989 for the 2nd record. The researcher met the mother/ caregiver at the Children's clinic or at home, as determined by the mother or caregiver, for the first day of the 24-hour recall. The mother was placed at ease in an environment away from distractions which was conducive to confidentiality. The 24-hour food intakes were complemented with the aid of three dimensional visuals and/or common household sizes. The recall was initiated by indicating the food eaten by the infant in the previous 24-hours beginning with the most recent intake. Upon completion of the food record, the mother's intake was recorded using the same procedure. Emphasis was placed on the number and size of the food portions and not on the quality or type of food eaten. The second 24 hour recall was completed in the home and often in the presence of the infant or siblings and other household members. Since the researcher was a professional dietitian accustomed to clinical teaching and dietary instruction, there was a chance that diet change would be initiated. The protocol was followed precisely to prevent bias and no dietary instruction was undertaken.

All mothers were instructed at the time of birth by a

Registered Nurse at the hospital on formula preparation, or appropriate breast feeding procedures, and the introduction of solid foods. (Appendices 8,9,10) At the six month clinic visit, a Registered Nurse reinforced the introduction of solid foods and for those who were using evaporated milk formula, the nurse provided written instructions for preparation of this formula. All questions of a dietary nature from the mothers were referred to the Registered Nurse who reinforced the dietary instruction according to the Children's Clinic protocol.

All interviews were conducted on Tuesday, Wednesday, Thursday, and Friday so that intake information collected was for weekdays only. It is reasonable to believe that weekend intake reflects usual intake. These days were chosen because this is the largest block of time during the week when the subject population were available and mothers verified that the intake on these days did not vary from the usual intake. Subjects were unavailable on the weekend days. The researcher was blind to the laboratory data at the time of the first series of dietary intakes.

4.1.4 Feeding and childcare questionnaire

The feeding and childcare questionnaire formed one part of the initial interview with the mother or caregiver. The questionnaire was developed by the researcher, who also

conducted all the interviews. The questionnaire was designed to document: 1) the mother's belief about quality of the diet for the infant; 2) the mother's ability to respond to the baby's signals of hunger; and 3) the mother's belief about coping with any of the most common disorders of infancy.

A structured face-to-face interview format with open-ended questions was used. Care was taken to assure the mother/caregiver that there were no right or wrong answers.

A total of 20 mothers at the Neonatal Clinic were interviewed to pre-test the questionnaire. On three separate occasions mothers were interviewed using the preliminary questionnaire to improve the layout and to clarify unclear and awkward wording. When the scoring of the questionnaire by the researcher and an independent advisor were interchanged the questionnaire was finalized and administered to all mothers or caregivers.

The feeding and childcare questions were used singly and by combining questions to provide additional scores. These scores were used to predict the iron status of the infant. Scores ranged from 1 (optimal), 2 (adequate), 3 (poor).

4.1.5 Social support needs assessment

The social support needs assessment formed one part of the initial series of interviews. The social support needs assessment was completed in the home on the second day of the

first data collection series. This gave the researcher an opportunity to interview the mother in an atmosphere of privacy, confidentiality and trust. The mother's perception of need was recorded and the researcher's opinion was also noted at the time of the interview.

The questionnaire was a modification of the questionnaire used by the Healthy Parent Health Child program (Sevenhuysen,1986). The assessment score was based on the mother's perception of her social situation and social support. The categories were:

1. PHYSICAL ENVIRONMENT which included, not only the type of housing but, the way in which she cares for her surroundings.
2. HISTORY, LIFESTYLE AND BELIEFS which included the mother's relationship to outside institutions which aided in her ability to cope with the growth and development of the infant.
3. INTERPERSONAL RELATIONSHIPS AND INTERACTIONS which included her interaction with spouse/ family and other household members. Spouse is used in this circumstance as any male partner of the mother.
4. FINANCIAL RESOURCES which included the amount of money available for food which will have a direct effect, not only on the nutrition of the infant, but on the mother as well.
5. FORMAL AND INFORMAL SOCIAL NETWORK which has a bearing on her ability to ask for help and assistance in child rearing

and other problems that arise.

6. STRENGTHS AND LIMITATIONS which included ability to cope with the ordinary stresses of life.

7. KNOWLEDGE OF GOOD HEALTH PRACTICES which included positive ways in which health care institutions and practices of prevention of diseases were used.

The scores ranged from 1 (complete), 2 (adequate), 3 (poor), to 4 (very poor).

4.1.6 Iron status parameters

All blood was drawn in the Children's Clinic by a Registered Nurse employed by the Behaviour and Developmental Study and who was experienced in venipuncture. At the time of the first and second records, venous blood samples were collected from subjects who were free of inflammation, for estimation of iron status. Inflammation is known to influence the accuracy of iron status parameters. Since free erythrocyte protoporphyrin (FEP) is markedly elevated in the presence of lead toxicity (Sassa et al.,1973), subjects with FEP >.9 fL had a further blood sample drawn for lead estimation at the subsequent appointment three months later.

All determinations were done by the laboratories of Clinical Chemistry, Hematology, and Nuclear Medicine

laboratories at HSC. Hemoglobin (Hb) and Mean Corpuscular Volume were determined by the cyanmethomoglobin method with a Coulter Hemoglobinometer (Coulter, Hialeah, FL), serum ferritin measured by radiometry and atomic absorption spectrohotometry using Abbot Quantum Spectometer. FEP was measured using Piomelli method (Perrotta,1987). Serum iron and total iron binding capacity were calculated using colorimetric procedures (Perrotta,1987) Percent saturation of transferrin was determined by dividing the serum iron by the TIBC and multiplying the result by 100.

All results were released to the Registered Nurse in charge of the Behaviour and Developmental Sample group, who in turn released the results to the researcher who entered the data into the University of Manitoba computer on the same day. The researcher did not review the laboratory data prior to the second series of data collection.

Optimal iron status was defined as hemoglobin (Hb) >90 g/l; mean corpuscular volume (MCV) >73 fL; serum ferritin (SF) >10 µg/l; transferrin saturation (TS) >12%; free erythrocyte porphyrin (FEP) <0.9 mg/L. Venipuncture blood was collected into tubes containing disodium ethylene diamine tetra-acetic acid (EDTA). A total of 7 cc blood was drawn for each series of tests; 1 cc for complete blood count (CBC) analysis, 3 cc for FEP in sodium heparin tube, 1 cc clotted specimen for SF, 3 cc clotted specimen for SI and TIBC. All specimens were labelled clearly. Blood was collected by a

HSC porter who transported it to the laboratory where the analysis was done on the day of collection.

4.1.7 Growth of infant

Diapered subjects were weighed by a Registered Nurse and an assistant using an integrating electronic balance (Toledo model #1365) with a precision of 10 g. Body measurements were carried out by a Registered Nurse or trained clinic aide and assistant with the infant in a supine position on a standard measuring apparatus with a stable head board and moveable foot board. The assistant held the infant's head, with the neck extended, to one end of the measuring board. The Registered Nurse extended the leg as much as possible, placed the heel flat against the board and recorded the length in cm to the nearest 5 mm. Birth weigh and length data were made available to the researcher from the HSC birth record. The length of the infant was rounded to the nearest largest cm since there appeared to be more than one technique used in measuring the newborn.

The standards used for anthropometry were the NCHS percentiles which are based on data from the United States. In the absence of appropriate standards for Canadian Indian children, these reference data were considered appropriate for this population.

CHAPTER 5

5.1 ANALYSES

5.1.1 Nutrient analysis

Data from the 24-hour recalls were coded by the researcher using the 1988 Canadian Nutrient File and entered into the Mainframe Computer at the University of Manitoba on the same day as the interview. These data were analyzed for energy (Kcal), protein (g), iron (mg), vitamin C (mg), fat (g), and carbohydrate (g) using the Nutrient Analysis Program (NAP) (Sevenhuysen,1984). The NAP program uses data from the 1988 Canadian Nutrient File as well as other food composition data which are available at the University.

All nutrient and energy intakes were calculated from a subfile numeration of amounts of food items reported in the recall interviews, except iron intakes. Those infants whose diet consisted primarily of breast milk, 800 ml of breast milk per day was entered into the dietary record (Dallman,1986B; Rios et al.,1975)

Since only a percentage of total iron is absorbed (Monsen et al. 1978; Rios et al,1975), an estimate of the amounts of available iron in each meal was calculated instead.

Monsen et al. (1978), in developing a model for iron absorption calculations based the measurements on the iron status and requirements of the menstruating female with 500 mg iron stores. Since the need for dietary iron is high in infancy assumptions of bio-availability used in this study are compared to those of the adult female. (Communication with Monsen,1989) (Appendices 11,12).

The procedure to calculate available iron was:

1) Estimate the amount of heme iron in each meal from the iron contribution of foods known to contain heme iron;

2) Calculate absorption of only 23% of heme iron for these iron amounts (Monsen and Balinfty (1982);

3) Estimate the amount of non-heme iron in each meal from the iron contribution of foods that do not contain heme iron;

4) Calculate absorption of only 2% for the non-heme iron amounts;

5) Calculate the amount of Vitamin C in each meal;

6) Calculate the absorption of non-heme iron at 8% of non-heme iron for the meal if more than 10 mg of vitamin C was available in that meal (Cook and Monsen, 1977);

7) Sum all amount of available iron to determine the amount of iron absorbed per subject per day.

5.1.2 Requirements per body weight

Body weight is an indicator of the weight of

metabolically active tissue iron. The amount of iron turnover is related to the speed of metabolism and the weight of tissue. Intake of iron per kilogram body weight is related, in part, to the rate of erythropoiesis as well as blood volume and therefore the demand for iron. Using the method of Czajka-Nairns et al.(1978), the mg available iron per subject by kilogram body weight to create an index that represented the requirements for iron.

5.1.3 Growth

Data on weight and length were converted to National Center for Health Statistics (NCHS) percentiles with the use of the CASP computer program provided by Centre for Disease Control (Jordon, 1987; Hamill,1977). This program calculates the percentile equivalents, and percent of medians for both weight and height for sex and age to the nearest quarter month. Changes in percentile distribution over time and between study groups were calculated.

5.1.4 Statistical analysis

The Statistical Analysis System (SAS) was used for analysis routines (SAS,1985). The researcher ensured quality control of coding survey questionnaires and the data entry into computer storage. The choices of statistical tests were

discussed with a consultant.

Univariate analysis was used to describe the population. The distribution of nutrient intakes were skewed for all nutrient cases. To achieve a normal distributions for nutrient intakes, values were transformed using logarithm to the base 10.

For statistical analysis all data from subjects were combined to provide a range of iron status. The level of significance for the calculations was set at probability less than 0.05. A paired Student's t-test analysis was performed to determine differences between the groups. Pearson's product moment correlation coefficients (r) and Spearman's correlation coefficients (p) were calculated to assess the relationship between nutrient intakes and social support needs assessment and iron status. The study data contained both discrete and continuous variables. Spearman's rank-order correlation coefficients were used to determine the degree of relationship between discrete variables.

CHAPTER SIX

6.1 DESCRIPTIVE RESULTS

The results of the data analysis are presented in three segments of this chapter. First, the structure of the final sample is described. Second, the descriptive results of the dietary intake of infant and mother, the iron status and anthropometry are presented by study groups. Finally, the correlation and regression analyses used to test the hypotheses are presented.

6.1.1 Subjects

The number of subjects in the study were fewer than planned because of 1) fewer births occurred among the non-referred patients than were predicted for the time period of data collection, and 2) more subjects than predicted dropped out of the BDS group due to high mobility of subjects.

Subjects were residents of the inner core of Winnipeg which is characterized by social variables such as poverty, family instability, and large family units (Social Planning Council, 1989). During the time of the study, 10 (17.8%)

subjects were removed from the parental home and placed in foster homes. Families who moved from their place of residence more than once during this 6 month period accounted from 35.8% of subjects. The majority (92%) of families lived on social assistance payments while only 8 % were employed. Mothers were pre-dominately Native, single and young (18-25 years), had more than one child, lived on social assistance benefits and in poor rental accommodations. Nine (16.1%) of the mothers were expecting another child at the time of the 1st record, an additional two mothers (19.6%) were pregnant at the time of the 2nd record.

A total of 56 subjects were enrolled in the study including one set of identical twins. Of these subjects, 20 were breast fed and 36 formula fed. For 53 subjects dietary and laboratory data records were completed for the 1st record. The three subjects excluded from the study at the time of the 1st record, included one who was breast fed for four days, one breast fed subject who moved out of the city, one formula fed subject who provided unreliable dietary data. During statistical analysis, four additional subjects were deemed to be outliers at record one because the individual mean of serum ferritin and/or transferrin saturation was greater than the overall mean plus three times the standard deviation. Therefore, the total number for the first record was 49 and 22 for the second record. The number of biochemical parameters varied because the amount of serum

collected was not sufficient for all tests and because of recording errors.

The period of breast feeding among 18 subjects ranged from six weeks to 12 months with the majority being weaned from the breast by five months. Solid foods were introduced as early as four weeks and as late as seven months with the majority receiving solid foods by five months. Breast fed infants were weaned from the breast to a formula of the mothers' choice with 55.5% of the infants being weaned to evaporated milk, 22.2% weaned to a commercial formula, and 22.2% weaned to cows' milk - homogenized and 2% fat content.

6.1.2 Description of groups

None of the variables, maternal age, birth weight, birth length or ages at enrollment were significantly different between any of the groups [Table 1]. Though the breast fed group was not randomly selected, these parameters did not differ from the formula fed subjects.

TABLE 1 DESCRIPTION OF GROUPS AT BIRTH

	FORTIFIED n=16 MEAN ±SD	NON-FORTIFIED n=18 MEAN ±SD	BREAST n=16 MEAN ±SD
MAT.AGE y	23.8 ± 6.23	21.70±4.64	20.9 ± 3.13
ENR.AGE m	6.65± 1.25	7.15±1.39	7.17± 1.18
BWT kg	3.62± 0.57	3.42±0.47	3.44± 0.54
BLT cm	52.87± 3.15	52.8 ±1.86	53.17± 2.65

MAT.AGE = maternal age expressed in years
ENR.AGE = age at enrollment expressed in months
BWt= birth weight expressed in kg
BLT= birth length expressed in cm

6.1.3 Social support needs scores and childcare

Social support needs scores ranged from one to four, with one being associated with the highest level of support. There were no significant differences between the scores of the three groups.

Childcare and feeding belief scores ranged from one to three, with one being associated with health providing beliefs and habits. Maternal risk score for poor pregnancy outcome ranged from zero to eight, with zero being the score of lowest risk. No significant differences were found between the groups for any of these variables.

Tables 1 and 2 indicate that the infants of the three groups were similar at birth with respect to maternal age, weight and length and age at the time of enrollment, and that their mothers showed similar responses to childcare and feeding beliefs question scores, social support needs scores situation and poor pregnancy risk. These results indicate that the infants were from the same population and up to the

time of enrollment no differences existed.

TABLE 2 MATERNAL CHARACTERISTICS
SCORES OF SOCIAL SUPPORT AND CHILDCARE

	FORTIFIED n=15		NON-FORTIFIED n=18		BREAST n=16	
	MEAN	±SD	MEAN	±SD	MEAN	±SD
SOCIAL SUPPORT						
MATERNAL PERCEPTION	2.0	0.86	1.8	0.92	1.8	0.83
RESEARCHER'S OPINION	2.35	0.93	2.2	0.98	2.4	0.96
FEEDING AND CHILDCARE BELIEFS						
FOOD ADEQUACY	1.3	0.72	1.4	0.85	1.1	0.50
FOOD BELIEFS	1.6	0.89	2.3	0.75	1.9	0.99
RESPONSE TO INFANT PHYSIOLOGY	1.6	0.89	1.6	0.84	1.6	0.87
FEEDING ROUTINE	1.5	0.89	1.5	0.92	1.4	0.71
FOOD PREPARATION	1.2	0.70	1.8	0.96	1.3	0.80
SOLID FOOD INTROD	2.1	0.74	2.0	0.76	2.1	0.80
PEER BELIEF	1.5	0.91	1.7	0.94	1.5	0.81
ILLNESS COPING	1.5	0.39	1.4	0.40	1.2	0.25
MATERNAL RESPONSE	1.5	0.51	1.5	0.38	1.4	0.35
FOOD CHOICES	1.6	0.60	2.0	0.52	1.7	0.71
WEANING TIME	1.6	0.38	1.8	0.48	1.6	0.40
MATERNAL RISK SCORE	1.7	1.77	2.6	3.10	1.4	2.18

6.1.4 Growth

The anthropometric data [Tables 3,4 and 5] indicate that there was no significant difference in the growth of the infants between the groups. The effect of fortification had no significant effect on the growth of the infants during the time period of the study.

TABLE 3

WEIGHT AND HEIGHT INDICATORS OF FORTIFIED FORMULA GROUP

	Record 1 n=15	Record 2 n=5
	MEAN ± SD	MEAN ± SD
Height/age%ile	55.46± 25.33	41.58± 22.04
Height/age med	100.87± 3.55	99.04± 2.4
Weight/age %ile	66.54± 26.25	53.44± 33.7
Weight/age med	107.38± 11.4	100.49± 13.09
Weight/height %ile	64.67± 27.5	56.62± 33.2
Weight/height med	104.83± 8.0	102.9 ± 9.31

TABLE 4

WEIGHT AND HEIGHT INDICATORS OF NON-FORTIFIED FORMULA GROUP

	Record 1 n=18	Record 2 n=9
	MEAN ± SD	MEAN ± SD
Height/age %ile	55.23± 26.98	61.32± 26.0
Height/age med	100.86± 5.45	101.43± 3.13
Weight/age %ile	71.52± 29.6	65.03± 40.0
Weight/age med	110.64± 13.47	107.2 ± 15.8
Weight/height %ile	70.2 ± 29.6	62.4 ± 38.23
Weight/height med	108.56± 12.11	105.54± 13.14

TABLE 5

WEIGHT AND HEIGHT INDICATORS OF BREAST FED GROUP

	Record 1 n=16	Record 2 n=8
	MEAN ± SD	MEAN ± SD
Height/age %ile	66.10± 29.63	42.01± 26.31
Height/age med	102.48± 5.12	99.39± 3.39
Weight/age %ile	70.50± 32.14	55.52± 35.77
Weight/age med	112.26± 17.65	103.29± 14.03
Weight/height %ile	66.85± 23.60	61.54± 28.06
Weight/height med	105.30± 7.76	105.30± 11.05

6.1.5 Dietary intake

6.1.5.1 Infant dietary intake

Table 6 shows that the dietary intake of the three groups was similar except for iron intake. The similarity between the randomly selected formula fed and non randomly selected breast fed group suggest all infants came from the same population and had the same cultural food practices.

TABLE 6

AGE AND DIETARY INTAKE OF INFANT

RECORD 1

	FORTIFIED n=15 MEAN±SD	NON-FORTIFIED n=18 MEAN±SD	BREAST n=16 MEAN±SD
AGE month	6.65±1.27	7.15±1.39	7.17±1.18
T.ENERGYkcal	860 ±207	905 ±297	930 ±343
T.VIT C mg	75 ±40	65 ±22	75 ±33
T.IRON mg	18 ± 7	6 ± 6	9 ± 9
Energy/kg	103 ±21	102 ±23	103 ±19

RECORD 2

	FORTIFIED n= 5 MEAN±SD	NON-FORTIFIED n= 9 MEAN±SD	BREAST n= 8 MEAN±SD
AGE month	12.1 ±0.53	12.1 ±0.47	12.2 ± 0.53
T.ENERGYkcal	1095 ±445	1089 ±218	1286 ± 636
T.VIT C mg	67 ± 40	66 ± 22	64 ± 70
T.IRON mg	16 ± 7	6 ± 3	7 ± 5
ENERGY/kg	113 ± 21	103 ± 21	124 ± 20

The quality and adequacy of the infant diets were compared to the Nutrition Recommendations for Canadians

(RNI,1990). At the time of the first record, the dietary intake was higher than the recommended amounts for infants for 6-8 months for protein (1.41 g/kg/day), vitamin C (20 mg/day) and iron (7 mg/day). Each one of these nutrients will be discussed separately.

The mean intake of protein at the time of the 1st record was 1.5 times greater than the recommended amounts and at the time of the 2nd record the mean intake was twice that of the RNI (1.37 g/kg/day). The range was from 9 to 82 g/d indicating a great variation in the daily intakes.

The dietary intake of energy from fat was 42.9% of total energy intake at the time of the first record, and 43.1% at the time of the second record. While the first record identifies an intake of polyunsaturated fat from formula, the second record reflects an intake of fat from processed meat, homogenized milk, butter and lard.

The energy requirements for infants are variable because of rapid growth, as well as individual activity patterns, demonstrated by small nonsignificant differences between the study groups. At the time of the first record, the fortified group had an average intake of 103 kcal/kg; the non-fortified 102 kcal/kg; and the breast fed group had 103 kcal/kg. These intakes are moderately higher than those reported by recent researchers Prentice et al.(1988) and Dewey et al. (1989).

The mean intake of vitamin C was three times that of the

recommended intake for infants at six and 12 months. The mean of the first record was 71 ± 31 mg. At the time of the second record the mean of intake was 65 ± 44 mg. The major sources of vitamin C were from the infant formula and vitamin C fortified breakfast-type drinks.

The mean intake of iron at the time of the first record was highest in the iron fortified formula group as expected. The differences in mean intakes between the groups were similar at 12 months, reflecting the effect of the formula feeding protocol of the Behaviour and Developmental Study. Previous to the second record, the diet of formula fed infants consisted almost exclusively of formula. The breast fed group tended to have more variety in their diets.

The use of iron fortified cereals in the study population was low (49.1%) at first record, and 11.3% at the time of second record. Research by Moe (1963) in Norway and Berg (1978) in the United States have stressed the importance of the contribution made by iron-fortified infant cereals in prevention of iron deficiency. The low consumption of cereals may be due to the high cost of such products and limited income of the mother.

TABLE 7

INFANTS WHO FAILED TO MEET THE RNI FOR IRON
RECOMMENDED INTAKE 7 mg/DAY

	FORTIFIED	NON-FORTIFIED	BREAST FED
RECORD 1	0/15	10/18	10/16
RECORD 2	0/5	7/9	5/8

All the infants in the fortified formula group met the RNI for iron while over one half of the infants in both the non-fortified formula and breast fed groups failed to meet the RNI at both records one and two.

TABLE 8

BIO-AVAILABILITY OF DIETARY IRON

mg/day

GROUP	RECORD 1 mean ± sd	RECORD 2 mean ± sd
FORTIFIED FORMULA	1.14 ± 0.33	0.89 ± 0.26
NON-FORTIFIED FORMULA	0.41 ± 0.51	0.36 ± 0.14
BREAST FED	0.62 ± 0.61	0.47 ± 0.27
REQUIREMENT[1]	0.5 - 0.8	

1 Dallman (1986B)

Table 8 indicates that the calculations for bio-availability of iron did not change for the group mean but did for the individual mean. The fortified formula group had sufficient iron available in the diet. Approximately 50% of the non-

fortified formula group and the breast fed group had insufficient available iron in the diet. The amount of available dietary iron decreased from record one to record two in all three groups.

TABLE 9

PROBABILITIES OF DIFFERENCES IN IRON INTAKE BY STUDY GROUP

RECORD 1

IRON INTAKE

	FORTIFIED VS. NON-FORTIFIED	NON-FORTIFIED VS.BREAST	FORTIFIED VS.BREAST
TOTAL mg	0.0010	0.3458	0.0002
AVAILABLE mg	0.0001	0.1893	0.0016
AVAILABLE mg/PER KG BODY WEIGHT	0.0002	0.3626	0.0137

RECORD 2

IRON INTAKE

	FORTIFIED VS. NON-FORTIFIED	NON-FORTIFIED VS.BREAST	FORTIFIED VS.BREAST
TOTAL mg	0.0034	0.6734	0.0640
AVAILABLE mg	0.0010	0.7131	0.1513
AVAILABLE mg/PER KG BODY WEIGHT	0.0008	0.3275	0.1272

The milligrams total iron intake, showed a statistically significant difference between the fortified formula and non-fortified formula groups (p=0.0010), and between the fortified formula and breast fed groups (p=0.0002) at six

months. This pattern of intakes did not change after making the adjustment for availability ($p=0.0001$) and infant weight requirements ($p=0.002$). The formula fed infants were dependent on formula for their dietary iron while the breast fed infants had more heme containing foods in their diets.

At the time of the second record, iron intake of the fortified formula group differed from the non-fortified formula group intake ($p=0.0034$), but did not differ significantly from the intakes of the breast fed infants. Adjustments for available iron based on body weight (kg) did not change this pattern of intakes. The breast fed and the non-fortified formula groups were not significantly different at either record 1 or record 2 using any of the methods of calculating the amount of iron in the diet.

The calculations of available iron was based on the assumptions of Monsen et al.(1978) and Czajka-Nairns (1978), and the adjusted intakes were expected to show greater associations with the amount of available iron in the diets of the infants than unadjusted intakes. The results of Student t-tests between groups do not contradict this association, but should be confirmed by differences in the strength of association of iron status with iron intake expressed in three different ways. Table 12 shows that the associations do differ and in the way predicted. Therefore all subsequent analyses have used iron intake adjusted for bio-availability and requirements.

6.1.5.2 Maternal dietary intake

There was no differences in the mean dietary intakes of the mothers at the time of the first record and the second record. The maternal diet was analyzed for 53 subject recalls at 1st record and 24 subject recalls at the time of the 2nd record. At the time of the first record, the mean nutrient intake of the mothers' diets were inadequate in all of the major nutrients and energy, with the exception of protein, when compared to the Nutrition Recommendations (1990) for women between the ages of 19 to 24 years. (Table 10).

TABLE 10 DESCRIPTION OF MATERNAL DIETARY INTAKE

RECORD 1			RECORD 2	
n=53		Mean ± SD	n=24	Mean ± SD
PRO	g	58 ± 27		53 ± 20
VITC	mg	61 ± 69		53 ± 47
IRON	mg	10 ± 5		10 ± 4
FAT	g	66 ± 38		58 ± 26
CHO	g	175 ± 92		193 ±106
ENERGY	Kcal	1522 ±756		1495 ±578

Of the 53 observations, 19 mothers (35.8%) had protein intakes of < 43 g/day while 12 (22.6%) had intakes twice the RNI at the second record. Although the proportion of energy from fat, at the time of the second record is within the recommendations of 30% of total energy made by the Canadian Consensus Conference on Cholesterol (1988), the intake is

largely composed of saturated animal fat from pork.

Maternal vitamin C intake ranged from 0.29 to 288 mg per day. The median intake of 38.7 mg/day was slightly below that of the RNI of 45 mg/day. Thirty-three mothers (62.3%) consumed diets which failed to meet the recommended amount. At the time of the second record, a similar percentage of maternal diets failed to meet the recommended amount. The intake of vitamin C was largely from vitamin C fortified breakfast type beverages.

Maternal dietary iron intake ranged from 2 to 28 mg/day at the time of the first record. No attempt was made to analyze the mothers diet for bio-availability of iron. The mean intake was 9.0 mg with SD ± 5.0 mg. Iron concentration, calculated as the amount of iron (mg) per 1000 kcal (Hallberg, 1981B), was 6.26 ± 6.6 at time of 1st record, and 6.45 ± 6.75 at the time of the 2nd record.

Regression analysis was done to determine if the mothers' diet could be a predictor of the infants' diet. Maternal energy intake was predictive of infant's energy intake for the whole group, but not for any of the feeding groups (F value= 7.594, p >F 0.0083). All other variables tested were nonsignificant.

6.1.6 Iron status and anthropometry

Table 11 shows little change in iron status and anthropometric values from record 1 to record 2 for the total group, except for an apparent decline in iron stores (ferritin 13.39 µg/L ± 11.47µg/L to 10.33 µg/L ± 9.47µg/L). A large number of infants had apparently inadequate iron stores at record 1 (n=49) and at record 2 (n=22), in spite of the fact that 1/3 of the infants received an iron fortified formula. Similar results are shown in tables 15,16,17 for each of the three groups.

TABLE 11 IRON STATUS PARAMETERS AND ANTHROPOMETRY
TOTAL GROUP

	RECORD 1		RECORD 2	
	Mean ± SD	n	Mean ± SD	n
AGE month	7.00 ± 1.28	49	12.19 ± 0.46	22
Hemoglobin g/L	110.53 ± 8.34	49	111.68 ± 6.65	22
Iron µmol/L	7.81 ± 3.94	48	8.23 ± 3.94	21
Ferritin µg/L	13.39 ±11.47	48	10.33 ± 9.47	21
Erythro protoph mg/L	0.75 ± 0.32	44	0.73 ± 0.29	20
Corpus.vol. µmol/L	75.08 ± 4.91	49	73.49 ± 4.55	23
Iron binding µg/L	66.88 ±11.25	43	67.80 ±11.36	20
Transf.sat. %	11.65 ± 6.01	43	12.6 ± 6.11	20
Height cm	69.42 ± 3.18	49	75.63 ± 2.42	22
Weight kg	8.78 ± 1.05	49	10.32 ± 1.42	22

6.2 ANALYSES BY HYPOTHESES

6.2.1 Hypothesis 1

There is a positive relationship between the dietary iron intake of the infant and the iron status of the infant.

Iron intake was expressed in three ways:
1). as calculated from food amounts (total mg);
2). adjusted for bio-availability of iron (available mg);
3). and adjusted for both iron bio-availability plus iron requirements (available mg/per kg body weight). Table 12 summarizes the results.

A significant relationship was found at the time of the 1st record between transferrin saturation ($p=0.04$, $r=0.31$) and total available iron and available iron expressed as available mg/per kg body weight ($p<0.01$ $r=0.39$). No other indicators of iron intake had a significant relationship with iron intake. At the 2nd record, there was no significant relationship found between any of the iron status indicators and iron intake.

Transferrin saturation is an indicator of recent iron intake. Serum iron and transferrin saturation vary both within days and across days in the same individual in relation to dietary intake. The dietary intake recall interviews were completed within a day of the blood sample. Therefore these findings indicate the recent ingestion of iron in the diet.

Throughout the presentation of results, the data for ferritin, transferrin saturation and mean corpuscular volume are shown. Data for hemoglobin or protoporphyrin measurements are not shown for the following reasons. Firstly, only one subject had a hemoglobin $\leq$ 90 g/L. Secondly, neither hemoglobin nor protoporphyrin were found to have a relationship with any of the independent variables investigated in this study. The interpretation of ferritin, transferrin saturation and mean corpuscular volume value is based on the stages of iron deficiency, which becomes apparent in three definite and overlapping stages: firstly, a decrease in iron stores is reflected in lower serum ferritin levels followed by a decrease in serum iron and an elevation in total iron binding capacity resulting in a low transferrin saturation, and finally a reduction in mean corpuscular volume, that may ultimately result in a decreased hemoglobin level. (Dallman,1986A).

TABLE 12 PROBABILITY ASSOCIATED WITH PEARSON'S PRODUCT MOMENT CORRELATION COEFFICIENT FOR SELECTED IRON STATUS PARAMETERS AND THREE IRON INTAKE ESTIMATES.

RECORD 1 (n=49)

IRON INTAKE	TRANSF.SAT.		CORPUS.VOL		FERRITIN	
	r	p value	r	p value	r	p value
TOTAL mg	0.27	0.07	0.20	0.16	0.14	0.31
AVAILABLE mg	0.31	0.04	0.26	0.06	0.14	0.31
AVAILABLE mg/PER KG BODY WEIGHT	0.39	<0.01	0.25	0.07	0.16	0.25

RECORD 2 (n=22)

	TRANSF.SAT.		CORPUS.VOL		FERRITIN	
	r	p value	r	p value	r	p value
TOTAL mg	0.37	0.15	0.02	0.93	0.41	0.09
AVAILABLE mg	0.49	=0.04	0.03	0.88	0.35	0.18
AVAILABLE mg/PER KG BODY WEIGHT	0.46	0.07	0.14	0.55	0.32	0.19

Regression analysis shows the same pattern of significance.

From these analyses, it is concluded that the dietary iron intake expressed as available mg iron per kg body weight is a usable indicator of the amount of available iron in the diets of the infants based on the assumptions of Monsen et al. (1978) and Czajka-Nairns (1978). All subsequent analyses of iron intake employ the adjusted iron intake using the assumptions of these authors.

The iron intake was statistically significance with transferrin saturation ($p<0.01$) indicating that there is inadequate iron in the diet which will ultimately lead to iron deficiency in this sample. At the time of record two there was no statistical significance.

TABLE 13

PROBABILITY ASSOCIATED WITH STUDENT'S t-TEST VALUES FOR SIGNIFICANCE BETWEEN IRON INTAKE AND SELECTED IRON STATUS PARAMETERS.

	RECORD 1 (n=49)	RECORD 2 (n=22)
FERRITIN	0.25	0.19
TRANSFERRIN SATURATION	<0.01	O.O7
MEAN CORPUSCULAR VOLUME	0.07	0.55

A further analysis was done using an index that was independent of the energy intake in the diet. The index consisted of the residuals of the regression of iron intake as the dependent variable and total energy intake as the independent variable. The residuals were then used in correlation with iron status parameters.

The index is reflective of iron quality independent of energy. It minimizes the variability of iron intake between infants due to amounts of foods eaten and may therefore reflect more closely long term intake. The index was expected to show an association with long term iron status indicators. However no significant relationship between any of the iron status parameters and the index at record one and record two was observed. This finding suggests that the dietary intake

was quite variable. The dietary data was collected on a visit to the clinic and the following day. The dietary intake may be reflective of the clinic protocol for these days while on other days there is much variation in the intake of iron.

TABLE 14

REGRESSION OF RESIDUALS OF IRON INTAKE AGAINST IRON STATUS PARAMETERS

IRON STATUS PARAMETERS	RECORD 1 (n=49)	
	r	p value
SERUM FERRITIN	0.058	0.25
TRANSFERRIN SATURATION	0.066	0.08
MEAN CORPUSCULAR VOLUME	0.052	0.11

The first hypothesis that there is a positive relationship between the dietary iron intake of the infant and the iron status of the infant is supported.

6.2.2 Hypothesis 2

Fortification of an infant formula with iron improves the iron status of the infant.

Tables 15, 16, and 17 display the iron status and anthropometry of the three groups.

Table 18 displays significant differences between the fortified formula group and the breast fed group for ferritin values for record one ($p<0.01$) and mean corpuscular volume ($p=0.05$) and in addition transferrin saturation ($p=0.02$) at record two. Significant differences between the fortified formula group and the non-fortified formula group were found in mean corpuscular volume for record one ($p<0.01$).

Significant differences between the fortified formula group and the non-fortified formula group were found in ferritin ($p=0.04$) at record two. At record two, the breast fed group was statistically significantly different from the fortified formula group. The breast fed group had a lesser dependency on milk as a source of iron and consequently had more variety in their diets which had lower iron content which is indicated by the significance of transferrin ($p< 0.01$). As a consequence the iron stores are utilized to maintain a normal hemoglobin.

TABLE 15

DESCRIPTION OF IRON STATUS AND ANTHROPOMETRY

	FORTIFIED GROUP RECORD 1 Mean ± SD	n	RECORD 2 Mean ± SD	n
AGE month	6.65 ± 1.25	15	12.19± 0.46	5
Hemoglobin g/L	112.53 ± 7.05	15	113.8 ± 2.58	5
Iron µmol/L	7.93 ± 3.91	15	9.60± 3.71	5
Ferritin µg/L	19.86 ± 9.00	15	20.40±11.23	5
Erythro protoph mg/L	0.68 ± 0.22	14	0.60± 0.22	5
Corpus.vol. µmol/L	77.70 ± 2.53	15	75.96± 3.48	5
Iron binding µg/L	59.14 ± 8.76	15	52.8 ± 4.54	5
Transf.sat. %	13.0 ± 6.1	14	18.05± 6.53	5
Height cm	68.24 ± 3.05	15	74.20± 1.74	5
Weight kg	8.34 ± 0.93	15	9.67± 1.28	5

TABLE 16

DESCRIPTION OF IRON STATUS AND ANTHROPOMETRY
NON-FORTIFIED GROUP

	RECORD 1		RECORD 2	
	Mean ± SD	n	Mean ± SD	n
AGE month	7.17 ± 1.39	18	12.13±0.46	9
Hemoglobin g/L	110.11 ± 6.90	18	112.4 ±8.36	9
Iron µmol/L	7.35 ± 2.78	17	8.88±3.98	9
Ferritin µg/L	13.88 ±14.19	17	8.75±7.90	8
Erythro protoph mg/L	0.72 ± 0.20	18	0.71±0.14	8
Corpus.vol. µmol/L	74.09 ± 4.51	18	74.45±4.79	9
Iron binding µg/L	71.2 ±13.05	15	72.7 ±8.59	8
Transf.sat. %	10.0 ± 4.00	15	12.6 ±4.13	8
Height cm	69.5 ± 3.46	18	76.5 ±2.25	9
Weight kg	8.92 ± 0.97	18	10.61±1.58	9

TABLE 17

DESCRIPTION OF IRON STATUS AND ANTHROPOMETRY
BREAST FED GROUP

		RECORD 1		RECORD 2	
		Mean ± SD	n	Mean ± SD	n
AGE month		7.17 ± 1.88	16	12.19± 0.52	8
Hemoglobin	g/L	109.12 ±10.67	16	109.5 ± 6.39	8
Iron	µmol/L	8.18 ± 5.08	16	6.42± 3.95	7
Ferritin	µg/L	6.81 ± 5.79	16	5.62± 4.59	8
Erythro protoph	mg/L	0.88 ± 0.50	12	0.84± 0.42	7
Corpus.vol.	µmol/L	73.73 ± 6.17	16	71.17± 4.14	8
Iron binding	µg/L	70.00 ± 7.26	14	72.85± 7.69	7
Transf.sat.	%	11.80 ± 7.00	14	8.76± 5.29	7
Height	cm	70.45 ± 2.27	16	75.52± 2.74	8
Weight	kg	9.90 ± 1.15	16	10.28± 1.34	8

To test this hypothesis, Student's t-tests for significance between groups were computed.

TABLE 18

PROBABILITY ASSOCIATED WITH STUDENT'S t-TEST OF SIGNIFICANCE BETWEEN GROUP IRON STATUS DIFFERENCES.

RECORD 1

	FORTIFIED VS. NON-FORTIFIED	NON-FORTIFIED VS.BREAST	FORTIFIED VS.BREAST
FERRITIN	0.17	0.07	<0.01
TRANSF.SAT.	0.15	0.44	0.66
CORPUS.VOL	<0.01	0.84	=0.02

RECORD 2

	FORTIFIED VS. NON-FORTIFIED	NON-FORTIFIED VS.BREAST	FORTIFIED VS.BREAST
FERRITIN	=0.04	0.35	<0.01
TRANSF.SAT.	0.09	0.13	=0.02
CORPUS.VOL	0.54	0.14	=0.05

The fortified formula group was significantly different for at least one of the dependent variables. The effect of fortification on the fortified formula group maintained the blood parameters within a normal range.

The hypothesis that fortification of an infant formula with iron improves the iron status of the infant is supported.

6.2.3 Hypothesis 3

There is no difference in the growth velocity between those infants whose diets contained iron fortified formula

and those whose diets contained a non-fortified formula or were breast fed and weaned to a milk of the mother's choice.

The growth of the infants in the study groups was compared in testing this hypothesis.

At birth, there were no differences in the weights or lengths of the infants. At 12 months of age the weight and length of the infants were not significantly different indicating that iron fortification had no effect on the anthropometric measures of this sample of infants.

This hypothesis is supported.

TABLE 19

GROWTH COMPARISON BY GROUPS
MEAN ± SEM* WEIGHT IN KG

AGE	FORTIFIED GROUP MEAN ± SEM	NON-FORTIFIED MEAN ± SEM	BREAST MEAN ± SEM
BIRTH	3.42 ± 0.12	3.44 ± 0.13	3.62 ± 0.14
12 M	9.67 ± 0.57	10.61 ± 0.52	10.38 ± 0.14
	MEAN ± SEM LENGTH IN CM		
BIRTH	52.8 ± 0.48	53.2 ± 0.64	52.8 ± 0.78
12 M	74.2 ± 0.78	74.4 ± 0.75	75.5 ± 0.69

*Standard Error of the Mean

6.2.4 Hypothesis 4

There is an inverse relationship between the feeding and childcare belief scores, and the iron intake of the infant at

the time of the first record and at the time of the second record.

The hypothesized relationship would be demonstrated by a negative correlation, since a low score for feeding and childcare beliefs indicates optimal responses for infant health is associated with high amounts of dietary iron intake.

Correlation between feeding and childcare belief scores and iron intake at the time of the first record did not show statistically significant relationships. However, at the time of the second record, iron intake correlated with the variable food choices ($\underline{p} = -0.56$, $p=0.025$).

The food choices variable was formulated by adding the scores of the question on maternal food beliefs and the question on kinds of foods peers would suggest that would be fed in the infant's bottle. The question on maternal food beliefs describes the foods that the mother felt to be especially health giving for the infant.

TABLE 20

SPEARMAN'S RANK-ORDER CORRELATION BETWEEN IRON INTAKE AND MATERNAL BELIEFS, FEEDING AND CHILDCARE HABITS.

	Correlation coeff. $\underline{p}$	p value
RECORD 1		
MATERNAL RESPONSE	-0.12	ns
FOOD CHOICES	0.01	ns
WEANING TIME	0.03	ns
RECORD 2		
MATERNAL RESPONSE	-0.19	ns
FOOD CHOICES	-0.56	>0.025
WEANING TIME	-0.07	ns

The correlation coefficient of -0.56 indicates a strong relationship between these two variables. Therefore the hypothesis that there is an inverse relationship between the feeding and childcare beliefs scores, and the iron intake of the infant at the time of the second record is supported for infant feeding beliefs about food choices.

6.2.5 Hypothesis 5

Feeding beliefs of the mother can predict high and low iron status in the infant.

There is no statistically significant relationship between any of the feeding and childcare beliefs of the mother and the iron status of the infant at the time of the 1st record. At the time of the 2nd record, one significant

relationship was identified as shown in table 21. However, the results do not show a consistent pattern that can be explained. The significant finding is therefore assumed to have occurred by chance. It is possible that either the sample was too small or the questionnaire may not have been sensitive enough to detect a difference between mothers' beliefs about feeding and childcare, and should be validated for use in predicting high or low iron status. The hypothesis is not supported for the feeding and childcare beliefs in predicting the iron status.

TABLE 21 SPEARMAN'S CORRELATION OF FEEDING BELIEFS WITH THE IRON STATUS OF THE INFANT AT 2ND RECORD.

RECORD 2	Ferritin	Trans.sat	mean corp vol
FOOD ADEQUACY	ns	ns	ns
FOOD BELIEFS	ns	ns	ns
RESPONSE TO INFANT			
PHYSIOLOGY	ns	ns	0.05
FEEDING ROUTINE	ns	ns	ns
FOOD PREPARATION	ns	ns	ns
SOLID FOOD INTROD	ns	ns	ns
PEER BELIEF	ns	ns	ns
ILLNESS COPING	ns	ns	ns
MATERNAL RESPONSE	ns	ns	ns
FOOD CHOICES	ns	ns	ns
WEANING TIME	ns	ns	ns

6.2.6 Hypothesis 6

There is a positive relationship between social support needs score of the mother and the iron status of the infant.

A negative correlation is anticipated since a high level of support is associated with a low score and is correlated with a high value for iron status.

The need for social support as perceived by the researcher is statistically significant when correlated with ferritin at record 1 [Table 21]. Table 21 indicates the strength of the association ($\underline{p}$=0.38, p>0.01).

This hypothesis is supported.

TABLE 22

PROBABILITY ASSOCIATED WITH SPEARMAN'S RANK-ORDER CORRELATION COEFFICIENT OF SOCIAL SUPPORT AND THE IRON STATUS OF THE INFANT AT 1ST AND 2ND RECORD.

RECORD 1	Mother's perception		Researcher's opin.	
	Corr. Coef. $\underline{p}$	p value	Corr. Coef. $\underline{p}$	p value
FERRITIN	-0.24	ns	-0.38	>0.01
TRANSF. SAT	-0.14	ns	-0.17	ns
CORP.VOL	0.33	ns	0.23	ns

RECORD 2	Mother's perception		Researcher's opin.	
	Corr. Coef. $\underline{p}$	prob p value	Corr. Coef. $\underline{p}$	prob p value
FERRITIN	-0.12	ns	-0.05	ns
TRANSF. SAT	-0.14	ns	-0.22	ns
CORP.VOL	0.14	ns	0.17	ns

CHAPTER 7

7.1 DISCUSSION

Iron status becomes abnormal in three definite but overlapping stages. The first stage is characterized by a decrease in serum iron and an elevation in total iron binding capacity resulting in a low transferrin saturation. Stage two involves a decrease in iron stores that is reflected in decreased serum ferritin values. The third stage shows a gradual decrease in the production of hemoglobin (Dallman, 1986A). The results indicate that several factors influence the iron status of the infants studied.

7.2 EFFECT OF FORTIFICATION

There was a statistically significant difference in iron status between the fortified formula group and the non-fortified formula group. In spite of the fortification of formula with 1.27 mg/100 ml ferrous sulfate, 13.3 % of the infants in the fortified formula group had low iron status as demonstrated by serum ferritin $\leq$ 10 µg/L and 57 % had transferrin saturation level $\leq$ 12%. [Table 15]. Larger numbers of the non-fortified formula group had low serum ferritin ($\leq$ 10µg/L), transferrin saturation ($\leq$ 12%) and mean

corpuscular volume ($\leq$ 73 fL) values at records one and two. [Table 16] The breast fed group exhibited on average the lowest iron status of the study groups.

Low maternal iron intake did not predict infants' iron intake. When both intake variables expressed as milligrams per day no statistical significance was found.

Fortification of infant formulas with iron improves the iron status of infants. Even though the infants had access to iron in the formula, it appears that the iron did not protect all infants from low iron status. Possible explanations for this finding are; 1) differential iron status at birth, possibly due to differences in maternal iron status, or delivery procedures which could influence the iron status; 2) gastro-intestinal bleeding; 3) failure to comply with the feeding protocol; 4) presence of inhibitors of iron absorption in the diet.

The design of this study included an estimate of the mother's iron stores from serum ferritin at the time of birth. Due to the constraints on data collection and the age of the infants at enrollment [Table 1]) too few maternal blood samples were available for analysis. Therefore it is not known to what extent maternal iron status may have contributed to differences in the iron status of the infants. Hallberg (1988) and Rios et al.(1975) have noted that adequate maternal iron stores before pregnancy will allow 250 mg to be drawn from them to meet the peak demands of

pregnancy supplemented by iron from dietary sources. Conversely, low maternal iron stores require that the full cost of pregnancy has to be met from dietary sources on a daily basis, and peak rates of iron utilization would impose a major increase in the dietary requirement.

With respect to gastro-intestinal bleeding, no attempt was made to document its' occurrence in this study, although, the nurse did ask the mother, at the time of the collection of blood for analysis, if there was anything unusual about the infants' bowel pattern. Hence, no conclusion can be made about the influence of this factor on the infants iron status.

Compliance with the study protocol may have been influenced by cultural factors. Young (1988), in an extensive review of the literature on cultural and eating patterns of Natives in the high Arctic, indicated that Indian people were very willing to share their food and resources with others. Many of the subjects, both in the Behaviour and Developmental Study and in the breast feeding group, were relatives as well as friends. One mother, from the breast fed group, indicated that when she had no money for formula she would get some formula from her cousin who was "on an iron study at the HSC". Such responses were not elicited systematically and the prevalence of sharing formula is not known. However, this response weakens the assumptions about formula intake inherent in the study design. Infants who

were given free formula may not have consumed their daily allowance, but shared the allowance with siblings, relatives and/or friends. Such behaviour could explain why several infants in the fortified formula group did not benefit from the protective effect of iron fortification.

Sevenhuysen (1986), in the report of the Healthy Parent-Healthy Child study in Winnipeg, reported that women responded to a culturally appropriate aide-assisted service by approaching existing health care staff more often. This finding obtained from a culturally similar group, indicates that women will more readily trust and confide in a culturally appropriate aide than in a professional of a different cultural group. The researcher was not of the same cultural group which may have weakened the accuracy of dietary, social support needs, feeding and childcare data. Alcohol consumption is known to be a problem in the urban Native community (Social Planning Council, 1987). Yet less than 2% reported consuming alcohol suggesting that the dietary intake may be incomplete.

Other than a study by Rios et al. (1975) on the absorption of iron from supplements in infant cereals and infant formulas the iron absorption studies been conducted in adult subjects. Hence, assumptions about iron absorption rates determined in adults were used in this study.

A common food that is known to inhibit the absorption of iron is egg yolk. In this study, mothers reported that 18.8%

of the infants at record one had consumed egg yolk, while the second record indicated that 29.2% had consumed egg yolk at a meal. The inhibiting effect of phosvitin in the egg yolk is not limited to the iron contained in the egg yolk but depresses absorption of iron from all foods taken with it (Dallman,1986A). Another food known to inhibit iron absorption is tea. Although Young (1979) and Moffatt (1988) reported that Native mothers feed their infants tea, only two mothers in this study reported tea was given to the infant. This may be due to the consistent teaching by the Childrens' Clinic staff or alternatively mothers failed to report the consumption of tea. In this study, no attempt was made to adjust for inhibitors of iron absorption in the diet because 1) the frequency of intake was small; 2) data for inhibitors of iron absorption was for adult subjects; 3) absorption rates vary greatly and these rates were low compared to the effect of absorption enhancers.

Ascorbic acid is one of the most effective dietary factors which increases non-heme absorption (Monsen,1988). The enhancing effect is seen only when consumed in the same meal. Ascorbic acid is an oxidizing agent and is also capable of chelating iron. Thus it can maintain iron in a soluble complex where it can be released at the gut wall. Meat, fish, poultry often called "the meat effect" also enhances iron absorption. It has been proposed that certain amino acids and intermediary products of meat, fish and

poultry digestion chelate with soluble iron and deliver iron to the gut mucosa.

In this study, estimates of iron intake in mg intake per day did not show a statistical significant relationship with iron status as anticipated. This finding could be explained by three reasons; 1) the iron was not fully absorbed; 2) iron intake was inaccurately calculated by using tables of food composition data; or 3) the diet record did not reflect true food intake.

However, adjusting iron intake for the presence of ascorbic acid in the diet, and for the bio-availability of iron from heme containing foods, changed the relationship with iron status to show a statistically significant relationship ($r= 0.39$, $p<0.01$) [Table 12].

The lack of significant difference in iron status between the non-fortified group and the breast fed group is an indicator that the diets of both of these groups were similar and inadequate in iron to maintain healthy iron status when compared to the fortified group. The breast fed group consumed various formulas, including four (22.2%) infants who were weaned to an iron fortified formula. Approximately 55% of the breast fed infants consumed evaporated milk as reported by the mother. The iron content of evaporated milk is 0.19 mg/100 ml. The remaining breast fed infants were weaned to cows' milk which contained 0.05 mg iron /100 ml. (Canadian Nutrient File, 1988).

Researchers have suggested that breast fed infants would be expected to consume 800 ml/day (Dallman 1986A). The data suggests that the assumptions of 800 mg per day may have been too high. McMillan et al.(1976) and Saarinen and Siimes (1979) have reported the high bio-available iron from breast milk. The data suggests that the assumptions may have been too large since the breast fed infants have the lowest iron status. The mean energy intake appears to be slightly higher than the two formula fed groups.

Reddy (1987) speculated that many of the weaning food used by the lower SES groups is only a slight modification of the common diet at home, which is often low in iron. Such was observed in this study, with mothers 24 hour recalls indicating a range of iron intakes from 2 to 28 mg/day (mean 10 ± 5 mg) without any adjustment for bio-availability. [Table 10]

A study by Czajka-Nairns et al. (1978) found a significant relationship between iron intake and iron deficiency anemia in infants of a lower socio-economic group. The infants who consumed less iron, consumed more milk and were introduced to solid foods earlier than infants who were iron replete. In the present study, no attempt was made to collect data on the time of introduction of solid foods, only that the majority of mothers believed that solid foods should be introduced between four to six months of age. This variable was not statistically significant for any of the

blood parameters tested.

Previous studies by Marinez et al. (1985) and Montalto et al. (1986), which quantitated total dietary intake, have shown that infants who were fed either cows' milk or non-iron fortified formula had median intakes of iron below the recommended daily allowance, whereas those given a diet including iron-fortified formula had intakes above the RDA.

The early introduction of solid foods (3.5 months) had an effect on the iron nutrition of infants as demonstrated by Saarinen and Siimes, (1979). They reported that the total body iron (TBI) remained at the same level when solid foods were introduced to the breast fed infants. The non-supplemented cows' milk group had a lower increase in TBI than the iron supplemented group. The early introduction of solid foods in the present study may have been a factor contributing to the low serum ferritin values observed in the whole group. The dietary intake data was measured with a 24 hour recall instrument on two consecutive days. Possibly the mother overestimated or underestimated the amounts consumed by the infant although the food intake was determined with the aid of household measures and food models. One concern was that the mothers were not totally responsible for feeding the child, because these households had many residents and therefore multiple caregivers for the child. The situation may explain the discrepancy between the dietary intake and the biochemical parameters of iron status. The recall

interview reports food intake within a set time period and not usual frequency of intake of food items. Hence, the frequency of consumption of enhancers or inhibitors of iron absorption may not be recorded accurately or these days may not be representative of typical days.

7.3 FEEDING AND CHILDCARE BELIEFS AND IRON STATUS

Maternal beliefs about appropriate food choices for infant diets and maternal childcare habits were recorded to determine whether such factors were associated with iron status of the infant at the time of the interview or six months later. Answers to individual questions related to feeding and childcare beliefs did not show a statistically significant relationship with either iron intake or iron status of the child. However, a combination of the two questions on food beliefs was found to show a statistically significant correlation with iron intake ($\underline{p}$= -0.56, $p>0.02$) at the time of record two. The relationship suggests that answers to the two questions that make up this variable could predict iron status. Answers were obtained at the time of enrollment in the study. The answers concerned beliefs about health giving foods and peer beliefs about the choices of foods appropriate for use in the bottle.

The relationship between the maternal belief of what to

feed the infant at six months and the dietary iron intake at twelve months is statistically significant. The choice of weaning foods has an influence on the iron intake but not on iron status. The maternal beliefs about infant feeding are not related to iron status in this sample, though this finding may change with a larger sample size. Furthermore, the questions were very specific to the mother's beliefs about feeding and not general health behaviour, which might require an additional definition in its operationalization.

7.4 SOCIAL SUPPORT NEEDS SCORES AND IRON STATUS

The social circumstances of the mother may determine the ability of the mother to provide optimal nutrition for the infant. Spearman's rank-order correlation indicated that the researcher's opinion of the mothers' need for social support had a statistically significant relationship with the serum ferritin levels of the children at the time of record one ($\underline{p}$= 0.33, $p<0.01$).

While Dressler (1985) and Turner (1983) indicated that social support may have other health effects, the way in which the social support needs score was operationalized in this study did not show a statistically significant relationship with serum ferritin levels at the time of record two. This may be due to the small sample size as well as the

way the variable was operationalized.

Wethington and Kessler (1986), in an extensive review of literature on social support, concluded that perceived support is more important than received support in predicting adjustment of stressful life events. The Winnipeg Social Council report (1989) indicated that the single Native mother in Winnipeg faces many stressful life events including poverty, poor housing, unemployment and transiency. Social support for the mother then can be critical in assuring her that she has the resources to provide for her infant.

7.5 GROWTH

The data in this study is compared to studies where the growth velocity of Native infants were studied. The mean birth weight of the total group (3.49 kg) was comparable to the birth weights (3.41 kg) of a 1962 study of Indian infants (Health and Welfare,Canada, 1967). The birth weights of the formula fed infants (3.42 and 3.44 kg) were similar to the birth weights (3.5 kg) of the Cree and Ojibway infants living on reserves in Northern Manitoba (Coodin, Dilling, Haworth, 1974). The birth weights of the breast fed infants (3.62 kg) were similar to the birth weights (3.65 kg) of those of Indian infants born on reserves in Northern Ontario (Goldthorpe, 1975).

A study by Evers and Rand (1982) of Indian children in Southern Ontario, reported that the mean birth weight of their group was 3.33 kg and the weight at 12 m was 10.17 kg. In the present study, the fortified group had a birth weight of 3.42 ± 0.12 and a weight of 9.67 ±0.57 kg at 12 m; non-fortified group had a birth weight of 3.44 ± 0.13 and a weight of 10.61 ±0.52 kg at 12 m; breast fed group had a birth weight of 3.62 ± 0.14 and a weight of 10.38 ±0.14 kg at 12 [Table 17]. Since the number at 12 m record is small it is not appropriate to analyze the data by milk type.

Energy intake in this study was higher than that reported by recent researchers. Prentice et al. (1988), in a British study of 355 healthy infants, estimated that the energy intake of their group was from 83 to 85 kcal/kg at 6 to 9 months and 83 kcal/kg at 12 months. Similarly, Dewey et al. (1989), in a longitudinal study of breast and formula fed infants in California, reported that breast fed infants showed an average intake of 78 to 87 kcal/kg at 6 to 9 months and 89 kcal/kg at 12 months of age. However, the formula fed infants had higher intakes averaging 91 kcal/kg at 6 months. The data for 12 m were not recorded.

CHAPTER 8

8.1 CONCLUSIONS

The study presents data on the iron status of infants who were fed fortified and non-fortified formula. The fortification of formula with iron does improve iron status of infants in a high risk population. Infants consuming the iron fortified formula have higher values for two iron status parameters. Therefore it is concluded that intervention to increase dietary iron intake above the iron intake from the regular infant diet will increase the iron status of the infant as defined by higher levels of ferritin and transferrin saturation ($P<0.01$) [Table 13]. In addition, the study was designed to investigate non-intervention variables that might predict the iron status of the infant. Dietary iron is assumed to change with intake and hence, predict iron status following evidence from clinical studies and the effect of iron fortification in this study. But estimates of total iron intake in milligrams per day did not show a statistically significant relationship with any indicator of iron status. Hence, the calculated intake did not reflect what was absorbed.

However, calculating bio-available iron in the diet did show a statistically significant relationship between iron

intake and transferrin saturation. None of the other four iron status variables used in this study showed a statistically significant relationship with the dietary iron intake. Since the transferrin saturation levels in part reflect daily iron intake, the dietary iron recorded in this study appears to reflect short term intake. Only repeated estimates of dietary iron would then estimate the long iron term iron status of the infant.

Maternal energy intake was associated with infant energy intake explaining 12% of the variability. However, neither maternal energy nor maternal iron intake showed a significant relationship with infant iron intake, thus maternal intake can not be used to predict infant iron intake.

Results show that maternal beliefs about appropriate infant food choices at 6 months are associated with infant intake at 12 months. The mothers' views about appropriate food to feed the infant and the beliefs of her peers on food choice could therefore be used to predict the infant's iron intake. The choices of weaning foods is an important indicator of iron intake.

Maternal score for risk of poor pregnancy outcome which describes the medical complications fo pregnancy and the physical status of the women at term, was not significantly related to infant iron status. The iron status of the mother at the time of delivery was not included in this analysis and the association of their specific indicators with infant iron

status is not known.

The need for social support, as perceived by a health professional when infants were six months of age, showed a statistically significant relationship with ferritin at six months ($p>0.01$). Both the need for social support as perceived by a health professional and the mothers' beliefs about appropriate infant diet food choices could be used to predict the iron status of the infant. The finding suggests that infant iron status is associated with maternal health related behaviours are influenced by the social environment.

8.2 FURTHER RESEARCH

The findings, suggest that further investigations on the calculations of bio-availability of dietary iron be carried out with infants six and 12 months of age. Not only calculations for the enhancing effects of ascorbic acid and meat/fish/poultry factor but also the inhibiting effects of other foods, may be valuable in explaining the reason why infants have low iron status in spite of the presence of iron dense foods in the diet.

Further investigation of the association of social interactions of social support on the iron status of the infant is warranted.

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LIST OF APPENDICES

APPENDIX 1
Subject no.____

Hello, my name is Irene Doyle.

I am a graduate student in Foods and Nutrition at the University of Manitoba. I am studying about the amount of iron a baby gets in his/her diet. Part of my study is on how a mother feeds her baby. Since mothers know how and when to feed a baby and also what foods should be given, I am visiting mothers and inviting them to talk to me about the baby and about feeding habits. I would like to talk to you about feeding. Your name or your baby's name will not be used and the information will not identify you in any way. There are no right or wrong answers. Your answers will not change any of the services that you are getting now or will get in the future. I simply want to know about the baby's diet and the best way to feed a baby.

Do you have any questions?

Thank you for your kind cooperation.

FEEDING AND CHILDCARE QUESTIONNAIRE

OPTIMUM = 1; ADEQUATE = 2; POOR = 3;

1. Responses are classified as optimum when the mother's responses indicate behaviour consistent with optimum development and growth of the infant or indicate awareness of infant physiology.

Responses are classified as poor when the mother's responses indicate a lack of awareness of infant growth and development or indicate behaviours that would promote ill health.

Responses are classified as adequate if the number of responses under optimal is equal to or greater than the responses in the poor category.

When a mother either breast-feeds or bottle feeds her baby, how does she know if the baby is getting enough to eat?

optimum	**adequate**	**poor**
-growing well	- combin-	-time for feeding is up
-wet diapers	ation of	-bottle is empty
-stops sucking/feeding	1&3	-RN,Dr,Mom said to feed this
-pushes the nipple from the mouth with tongue	-feed until full	this amount -baby is getting fat -don't know
-contented		
-goes to sleep		

2. Responses are classified as optimum when the mother's responses refer to heme containing, iron fortified foods or responses of foods containing high iron or vitamin C.

Responses are classified as poor when the mother's responses refer to foods with small amounts of iron, low vitamin C content and responses referring to infant feeding practices not associated with appropriate food choices.

Responses are classified as adequate if the number of responses under optimal is equal to or greater than the responses in the poor category.

Are there any foods that are especially health giving for a baby?

optimum	adequate	poor
-meat-red/ organ	-combination of 1&3	-white-poultry
-fish -shell	-evaporated milk	-egg white/yolk
-beans		-potatoes
-cereal(enriched)		-table food
-veg- high vit.C		-low vit.C
- high iron		-low iron
-fruit- high vit.C		-don't know

---

3. Responses are classified as optimum when the mother's response indicates her awareness of the infant's previous food intake or recognition of infant behaviour normally associated with hunger.

Responses are classified as poor when the mother's responses indicates her lack of awareness of the infant's previous food intake or recognition of infant behaviour normally associated with hunger.

Responses are classified as adequate if the number of responses under optimal is equal to or greater than the responses in the poor category.

When a baby is crying how does a mother know that he/she is hungry?

optimum	**adequate**	**poor**
-if time of last feeding exceeds 2-4 hours	-baby makes special sound	-baby always cries at meal times
-physical signs ie.sucking hand,rooting,cranky,	-try to remember when last fed	-just cries for food
-special kind of cry	-baby refuses soother	-won't stop crying
-recall the amount of last feeding	-total time allotted for breast feeding is up	-sucks thumb at time
-recall the amount of last feeding		-nothing else is ever wrong
-total time allotted		-don't know
-when a soother doesn't comfort		

---

4. Responses are classified as optimum when the mother's responses indicate appropriate frequency of feeding in relation to changing maturity or energy demands of the infant.

Responses are classified as poor when the mother's responses indicate inappropriate frequency of feeding in relation to changing maturity or energy demands of the infant.

Responses are classified as adequate if the number of responses under optimal is equal to or greater than the responses in the poor category.

How often should a baby be fed?

optimum	**adequate**	**poor**
- < 2months: on demand or every 2-3 hours -older,every 4-3 hours when hungry -depends on growth spurt -when hungry	-according to schedule or 2-4 hours	-when Dr. RN,PDt said to feed - -when I remember -3 times/day -when I have milk -schedule -don't know

---

5. Responses are classified as optimum when the mother's responses refer to food choices appropriate for the stage of physical development of the infant.

Responses are classified as poor when the mother's responses
refer to food choices inappropriate for the stage of physical development of the infant.

Responses are classified as adequate if the number of responses under optimal is equal to or greater than the responses in the poor category.

When a baby begins to eat foods other than milk/formula, how should the food be prepared for a baby?

optimum	adequate	poor
warm- pureed/mashed/ special liquified/blend -baby food jars	-warm chewed by mom -mashed from family meal	-nothing -table food -lots of fluid with a little food -don't know

---

6. Responses are classified as optimum when the mother's response is 6 months.

Responses are classified as poor when the mother's response is either < 4 or > 7 months.

Responses are classified as adequate if the mother's response is between 4-6 months.

At what age should a baby be given foods other than milk/formula?

optimum	adequate	poor
6 months	4- <6 months	0-<4 months > 7-9 months -don't know

---

7. Responses are classified as optimum when the mother's responses indicate that the fluids or foods that are placed in the bottle would promote good nutritional or dental health.

Responses are classified as poor when the mother's responses indicate inappropriate responses for adequate nutrition, or foods that would not promote good health.

Responses are classified as adequate if the number of responses under optimal is equal to or greater than the responses in the poor category and include evaporated milk.

What kinds of fluids/foods would your friends or relatives suggest should be put in the baby's bottle?

optimum	adequate	poor
-water	-evaporated milk	-tea/coffee
-formula		-pabulum
-juice		-synthetic fruit juice
		-gripe water
		-carbonated beverages
		-cookies in fluid
		-water with honey
		-water with sugar
		-water with syrup

---

8. Responses are classified as optimum when the mother's responses indicate medically or physiologically appropriate behaviour in the care of each of four disease symptoms. Appropriate behaviour includes feeding, providing fluids, seeking professional health care personnel.

Responses are classified as poor when the mother's responses indicate medically or physiologically inappropriate behaviour in the care of each of four disease symptoms.

Responses are classified as adequate if the number of responses under optimal is equal to or greater than the responses in the poor category.

What would your friends tell you to do if the baby has the following problems?

optimum	adequate	poor
constipation		
-lots of water then see Dr	-watch closely	-nothing
-fluids only then see Dr.	-suppository -exercise in warm water	-wait until has 2nd problem see Doctor
-don't know but will ask	-water and corn syrup	-beer
	-baby food prunes	-no milk
	-apple juice	-gripe water
		-alcoholic drink
		-don't know
		-manual help

---

fever

-give water
-bath in warm water
-take to Doctor
-acetaminophen
-don't know but will ask
-call Emergency nurse/doctor

-give fluids
-watch closely
-ask a neighbor/ friend
-call Native healer
-remove some clothing

-do nothing
-panic
-walk outside
-aspirin
-gripe water
-avoid milk
-don't know

____

colic

-walk, cuddle,
-sing
-wrap in blanket
-go to Dr. 1st time lots of TLC
-don't know but will ask

-give fluids
-feed
-call for assistance

-shake or hit
-leave alone home/room
-alcoholic-
-gripe water
-sniff rag
-nothing
-gripe water
-don't know

____

diarrhea

-clear fluids & call doctor
-watch closely
-go to a doctor
-no milk/formula
-don't know but will ask

-fluids
-call mother
-infant Donagel
-milk only

-roughage
-nothing
-wait til over
-gripe water
-nothing until another problem arises then see doctor
-no fluids
-change diapers
-don't know

____

Total( ) Average____

APPENDIX 2

Subject no._____

SOCIAL SUPPORT NEEDS QUESTIONNAIRE

PHYSICAL ENVIRONMENT.

Type: House or apartment? Number of rooms? Crowded? Sleeping arrangements? How long there? Plans to stay? Amount of furniture? Appropriate for lifestyle? Food preparation? Wash? Sleep? Storage? Sanitary facility? Things to read? Laundry facilities? Transport: car or public transport?

HISTORY, LIFESTYLE AND BELIEFS

Identity: Clear ethnic and cultural? Arrived recently from outside town? From where? Marital status: single, divorced, common law, married? Any impact of religion on life? Recent changes? Problems at present? What changes would she like to make in her life? How much is possible to change? What things will make it easier or harder for her to get what she wants? What things in her day-to-day situation make it easier or harder (money, transportation, etc.)

RELATIONSHIPS AND INTERACTIONS

Consider this to be within immediate household.
Responsibility sharing, making and spending money? Who? How much? Adequate? Any problems agreeing on budget? Other major decisions shared? Divergence of belief system and conflict. Attitude about child care and feeding habits? Attitude and influence of others about child care and feeding habits? Who helps to care for the child?

FINANCIAL RESOURCES

What the family members do: Mother: work, school, stay home, kind of work- education achieved? Her hopes of the future? Father: What kind of work, stay home, hours, education achieved, pay hours, plans, do you get help for money from others- family, friends? Are you ever short of money for rent or food? Why?

FORMAL AND INFORMAL SOCIAL NETWORK

Consider this to be out of immediate household.
Support for mother: if she has had a bad day what does she experience or motivation. Severe health problems. Health care not a priority. Failure to bond. Negative or no support system operative. Potential abuse or neglect. Any

physical abuse or neglect not remediated or stabilized. Failure to thrive for any reason. Severe parental deprivation. Coercive efforts needed to gain compliance with standard care.

APPENDIX 3

FACULTY OF HUMAN ECOLOGY

UNIVERSITY OF MANITOBA

APPROVAL FOR RESEARCH PROPOSAL INVOLVING HUMAN SUBJECTS

This is to certify that:

Irene Doyle

in the Department of Foods & Nutrition

presenting a proposal for a research project entitled:

Determinants of Iron Deficiency among Infants of High Risk Population Groups

The Faculty Ethics Subcommittee is satisfied that the appropriate ethical criteria for research involving human subjects have been met.

Members of the Subcommittee:

Name	Position	Department
M. Eskin	Professor	Foods & Nutrition
C. Gonzales	Associate Professor	Clothing & Textiles

Date: September 30, 1988

Subcommittee Chair

OCT 29 1987

APPENDIX 4

UNIVERSITY OF MANITOBA
FACULTY COMMITTEE ON THE USE OF HUMAN SUBJECTS IN RESEARCH

NAME: *Dr. M.E.K. Moffatt*

OUR REFERENCE: *E87:197*

DATE: *October 28, 1987*

YOUR PROJECT ENTITLED:

Behavioural and Developmental Effects of Iron in Infancy.

HAS BEEN APPROVED BY THE COMMITTEE AT THEIR MEETING OF:

October 26, 1987

COMMITTEE PROVISOS OR LIMITATIONS:

NONE

You will be asked at intervals for a status report. Any significant changes of the protocol should be reported to the Chairman for the Committee's consideration, in advance of implementation of such changes.

If you are applying for funds for this project, please advise the Committee Secretary whether or not you need a statement of local review committee for the granting agency.

** This approval is for the ethics of human use only. For the logistics of performing the study, approval should be sought from the relevant institution, if required.

Sincerely yours,

J. P. Maclean

J. P. Maclean, M. D.,
Chairman,
Faculty Committee on the Use of Human
Subjects in Research

JPM/cs

TELEPHONE ENQUIRIES:
788-6376 - Christine Sys

APPENDIX 5A.

CONSENT FORM FOR BREAST FED INFANTS

I,_____, give my consent to have my child, _____ and myself, participate in the research project on Iron Deficiency in infants. I consent to have a sample of my blood taken for serum ferritin estimation. I understand that the researcher, Irene Doyle, will visit me in my home when my child is six months old and again at twelve months of age, to ask me questions about my diet and my environment.

When my child is six months, and again when the child is 12 months, I understand I will be visited by the researcher on two consecutive days and asked questions about my diet as well as the diet of my baby. I also consent to have the nurse take a blood sample from my child at age six and twelve months to be used by the researcher.

If at any time I wish to withdraw from the study, I may do so and it will not affect the care received by my child at the Children's Clinic or from any physician.

All the results will be confidential. My identity and that of my child will not be made known in any published results of the study. Results of the study can be made available to all participating parents/guardians who wish to discuss them.

I agree to participate in the study on iron deficiency in infants. The study has been explained to me and I also understand that I have the right to withdraw from the study at any time and it will not affect the care of my child.

Signature:_____ Date:_____
Parent/Guardian

Witness: _____

Researcher_____

APPENDIX 5B.

CONSENT FORM FOR FORMULA FED INFANTS

I, _____, give my consent to have my child, _____ and myself, participate in the research project on Iron Deficiency in infants. I understand that the researcher, Irene Doyle, will visit me in my home when my child is six months old and again at twelve months of age, to ask me questions about my diet and my environment.

When my child is six months, and again when the child is 12 months, I understand I will be visited by the researcher on two consecutive days and asked questions about my diet as well as the diet of my child. I also consent to have the nurse take a blood sample from my child at age six and twelve months to be used by the researcher.

If at any time I wish to withdraw from the study, I may do so and it will not affect the care received by my child at the Children's Clinic or from any physician.

All the results will be confidential. My identity and that of my child will not be made known in any published results of the study. Results of the study can be made available to all participating parents/guardians who wish to discuss them.

I agree to participate in the study on iron deficiency in infants. The study has been explained to me and I also understand that I have the right to withdraw from the study at any time and it will not affect the care of my child.

Signature: _____ Date: _____
Parent/Guardian

Witness: _____

Researcher: _____

APPENDIX 5B.

CONSENT FORM FOR FORMULA FED INFANTS

I, _____, give my consent to have my child, _____ and myself, participate in the research project on Iron Deficiency in infants. I understand that the researcher, Irene Doyle, will visit me in my home when my child is six months old and again at twelve months of age, to ask me questions about my diet and my environment.

When my child is six months, and again when the child is 12 months, I understand I will be visited by the researcher on two consecutive days and asked questions about my diet as well as the diet of my child. I also consent to have the nurse take a blood sample from my child at age six and twelve months to be used by the researcher.

If at any time I wish to withdraw from the study, I may do so and it will not affect the care received by my child at the Children's Clinic or from any physician.

All the results will be confidential. My identity and that of my child will not be made known in any published results of the study. Results of the study can be made available to all participating parents/guardians who wish to discuss them.

I agree to participate in the study on iron deficiency in infants. The study has been explained to me and I also understand that I have the right to withdraw from the study at any time and it will not affect the care of my child.

Signature: _____ Date: _____
Parent/Guardian

Witness: _____

Researcher: _____

APPENDIX 6

CONSENT FORM

A STUDY OF THE EFFECTS OF IRON DEFICIENCY ON INFANT BEHAVIOUR AND DEVELOPMENT. Investigators: Dr. M.E.K. Moffatt, Dr. S. Longstaffe

The Children's Clinic of the Winnipeg Children's Hospital is conducting a study to determine whether there is a relationship between a lack of babies body iron and their behaviour and development.

We plan to ask parents who have already decided to bottle feed their babies, to participate. All children in the study will receive free a regular supply of infant formula for the first 12 months of life. One half of the participating babies will receive regular infant formula. The other half will receive formula with added iron. The participating families, and the study doctors will not know which group any particular baby is in until the end of the study. The free formula will be delivered to participating families every month.

If you decide to take part, you will be asked to come to Children's Hospital when your baby is 6, 9, 12 & 15 Month old. At each visit your baby would take part in a play session to test his/her behaviour and progress in development, and also a small blood sample will be taken. If at any time your child is found to be missing too much body iron he/she will be taken out of the study and given appropriate treatment.

One member of our research team will visit your home regularly to deliver the formula and will also visit at least once during the study to ask about your family, and any changes at home which could affect your child's performance on the developmental tests. He/she will also ask about, and observe how you play with your baby at home, and will try to answer any questions you may have.

If at any time you wish to withdraw from the study you may do so without compromising the care received by your child.

All the results will be confidential. Neither you nor your child will be identifiable in any published results of this study. Results of the study can be made available to all participating parents who wish to discuss them.

Should you have any questions about the procedures involved in the study, you may call:

I,_____(mother, father or legal guardian of

_____, agree to participate in the study of iron deficiency and behaviour. The study has been clearly explained to me and I also understand that I have the right to withdraw from the study at any time without compromising the care my child will receive.

_____ _____

SIGNATURE (Parent/Guardian) DATE

_____ _____

SIGNATURE (Witness) DATE

_____

PRINTED NAME OF WITNESS

Subject no. _____

Appendix 7
24 hour recall

Day 1, 2,3,4,5,6,7,8 first second interview for subject

TIME OF DAY	MEAL CODE 1, 2, 3, 4	FOOD ITEM	DESCRIPTION	FOOD CODE	AMOUNT CONSUMED	
					Grams	House Meas (Optic

Vitamin Supplements? Yes _____ No _____ If yes, state: Brand(s) _____

Dose (ie. no. tablet/day) _____ Content (mg. etc./tablet) _____

_____

APPENDIX 8

Health Sciences Centre

CHILDREN'S HOSPITAL
840 Sherbrook Street
Winnipeg, Manitoba R3A 1S1
Dial Direct (204)-

FORMULA-FED INFANTS (0-4-6 MONTHS)

Welcome to our Neonatal Clinic. Our goal is to provide a healthy, happy learning environment for you, your baby and your family.

YOUR BABY _____ AT _____

WEIGHS _____

MEASURES _____

Some Guidelines For Feeding Your Baby For The Next Few Months:

Formula your baby is using: _____

To mix the formula use: _____

_____

(The amount your baby takes varies with his eating habits.)

AGE	FEEDINGS	AMOUNT
1 - 2 Weeks	6 - 10/day	50 - 100 ml. (2-3 oz.)
3 Weeks - 2 Months	6 - 8/DAY	125 - 150 ML. (4-5 OZ.)
2 Months - 3 Months	5 - 6/day	150 - 175 ml. (5-6 oz.)
3 Months - 6 Months	4 - 5/day	175 - 250 ml. (6-9 oz.)

Feed your baby when he/she is hungry and let him/her regulate the amount of formula. Be careful not to over-feed him/her.

Supplements:
You can start giving your baby sugar water (4oz. boiled water with 1 tsp. sugar) and/or apple juice 1:1 if he/she is thirsty.

Trivisol:
If your baby is on evaporated milk, he/she should receive vitamins. He/she should get _____/day. Formulas such as Enfalac or Similac have vitamins prepared in the formula.

NOTE: Baby cereals and baby foods are not needed until your child is between 4 - 6 months old.

If your have any questions or concerns please call

_____ at _____

.../cont'd

Additional Notes:

LJ/db
January 13, 1986

NS00084

PREPARING EVAPORATED (CANNED) MILK FOR BABY

A mixture of evaporated milk, water and sugar is good for babies.

Evaporated milk has been heated by the manufacturer so that it is sterilized and easy to digest. Vitamins C and D have been added so be sure to use cooled, boiled water when preparing the milk to save the vitamin C. Ask your doctor about a fluoride and an iron drop.

The water should be boiled for 5-10 minutes, cooled and stored in a covered pot with the lid on, until ready to use.

1. Before opening the milk, wash the can and opener in hot soapy water and rinse with scalding hot water.
2. Then pour the required amount of evaporated milk into a sterilized container.
3. Add the sugar, and the recommended amount of cooled, boiled water. Mix well.
4. Pour into sterilized bottles.
5. Put a boiled nipple upside down in each bottle without touching the rim of the bottle or the nipple.
6. Cover the nipples at once with the boiled lids and caps, being careful not to touch the inside rim of the nipple caps with your hands. Put in a refrigerator or other cool place.

Bottles can be made up, one at a time, by pouring the milk and water into the bottle, and adding the sugar. Cover with the nipple turned in and the cap. holding it in place shake and store in the refrigerator.

NOTE: The amounts of milk, water and sugar change for different ages. Use the amounts that are right for your baby's age. A general guideline would be:

AGE OF BABY

Ingredients	Birth - 3 months	one bottle	3 - 6 months	one bottle	over 6 months	one bottle
Evaporated Milk	1 can	3 oz.	1 can	3 oz.	1 can	4 oz.
Water	1 1/2 can	5 oz.	1 1/2 can	4 1/2 oz.	1 can	4 oz.
Sugar	3 tbsp.	2 tsp.	2 tbsp.	2 tsp.	-	-

* Be sure to use evaporated homogenized milk. Evaporated partly skimmed milk is NOT RECOMMENDED FOR INFANTS UNDER ONE YEAR OF AGE. Do not use Sweetened Condensed Milk. These milks do not contain the right amounts of the vitamins, minerals, protein, and fat that the baby needs.

Manitoba Health
Health Promotion
1988

APPENDIX 10

INTRODUCTION TO SOLID FOODS

Mothers milk or formula has all the nutrients that your baby needs to keep him healthy for the first 4-6 months of life.

Feeding your baby solid food too early is not a good idea because:

- solid food may take the place of milk and milk is nutritionally better for your baby
- babies may have an allergic reaction to baby foods when fed too early
- research has not shown that solid food helps a baby sleep through the night.

WHEN IS MY BABY READY FOR SOLID FOOD?

Crying does not always mean your baby is hungry.
HINT: If it has been less than 2 hours since the last feeding try giving water first. If baby is satisfied, he's probably only thirsty. If not, try milk. If still unhappy, your baby may be ready for cereal. Cereal may settle a fussy baby one day, but that doesn't mean feeding cereal every day is necessary. Try milk first.

Many babies are happy on only milk for the first 6 months, so you can start feeding solid food when:

- your baby has control of his neck muscles
- your baby can sit up with support
- your baby takes a more active part in feeding - shows an interest and leans forward to take food; turns head away when not wanted.

WHEN TO INTRODUCE SOLID FOODS

CEREALS - add to diet at 5 - 6 months

- Baby cereals are introduced first. They provide the baby with added iron, vitamins and other important nutrients.
- Rice cereal is best to start with as children have the least allergic reaction to this grain and it is easy to digest.
- It can be mixed with formula, breast-milk or boiled water and mixed thin enough so that baby can swallow it.
- Never put formula in baby bottle - baby's should begin to get use to the consistency of cereals and to the feel of a spoon.
- Your baby will probably spit out a lot of cereal but don't worry the baby will soon get used to it.
- Mixed cereals should not be used until you know that your infant can digest all the different grains used in the mixed cereal.
- It is best to use rice first, then barley and oatmeal cereals.

FRUITS & VEGETABLES - add to diet at 6 - 8 months

- Fruits and vegetables are important because they contain Vitamins A & C.
- It is best to introduce vegetables first so that your baby doesn't get used to the sweet taste of fruit first.

5-6 months	6-8 months	8-9 months	10-11 months	12 months
Cereal - single grain - mix with formula, breast-milk or sterile water to appropriate consistency 8 tbsp.			10 tbsp.	
	Vegetables - single vegetables best - not mixtures 4 tbsp.	6-8 tbsp.	10 tbsp	
	Fruits - single fruits - best - not mixtures 4 tbsp.	6-8 tbsp.	8-10 tbsp.	
		Meats & Fish - single meats - not dinners 3 tbsp.	4 tbsp.	
			Egg Yolk - soft cooked	
				Whole Egg
				Milk in a cup
				Whole or 2% Cow's mil

* Amounts based on daily total amount
* Finger foods and table foods can be added after 9 months - try toast, bread sticks, soft cheese to start.
* Begin to offer baby milk in a cup and as he increases his intake, decrease the number of bottles per day.

9 mo.

APPENDIX 11

University of Manitoba,
Dept of Foods and Nutrition,
Faculty of Human Ecology,
Winnipeg, Manitoba
R3T 2N2
April 7, 1989

Dr. Elaine R. Monsen, Ph.D.
Division of Human Nutrition,
University of Washington,
Raitt Hall DL-10,
Seattle, WA 98195

Dear Dr. Monsen,

As a graduate student in Community Nutrition, I am researching Iron Deficiency in Infants of a low income population. I read, with interest, your papers in both the American Journal of Clinical Nutrition 31(1978) on Estimation of available dietary iron and Calculating dietary iron bioavailability: refinement and computerization in the J Am Diet Assoc 80(1982).

I am interested in knowing if there is sufficient variability between the types of meats to warrant differing values of heme and nonheme from meat, fish and poultry? What about fish,ie. crustaceans- mussels, clams, lobster, etc., in particular, and the meat that is not muscle, and the different parts of the animal? Would I be correct in assuming the same enhancing effect of ascorbic acid or animal tissue on heme, nonheme iron in infants? Should there be another set of criteria for the diet of infants?

With reference to the Microcomputer program data base, what food composition criteria was used for the data base and is this available in the literature? Does the program use the formula as discussed in J Am Diet Assoc 80:309 Calculating dietary iron bioavailability:refinement and computerization or does it make other decisions to calculate the dietary iron bioavailablity?

Has there been any recent publications on the bioavailability of dietary iron that I have overlooked? I appreciate you taking time from your busy schedule to respond.

Thank you, in advance, for your kind assistance.

Sincerely yours,

Irene A. Doyle
Graduate Student

APPENDIX 12

UNIVERSITY OF WASHINGTON
SEATTLE, WASHINGTON 98195

Nutritional Sciences, DL-10

April 18, 1989

Irene A. Doyle
University of Manitoba
Dept. of Foods & Nutrition
Faculty of Human Ecology
Winnipeg, Manitoba R3T 2N2

Dear Ms. Doyle:

You ask several very important questions regarding the calculation of available iron in the diet. I shall take them up one by one.

First, heme iron content does differ in meat, fish and poultry. Most likely, it also differs by the age and condition of the animal, fish, or fowl. I assume that heme content ranges, at least, from 40-60% of total iron. The estimates of iron content in meats have been revised a few years ago by the USDA; current Handbook 8 values reflect these revisions.

Second, ascorbic acid enhances absorption of nonheme iron, but does not appear to enhance absorption of heme iron.

Third, for questions on the microcomputer program database, please check with Dr. Joseph Balintfy. The most recent address I have for Dr. Balintfy is Professor of Food Management Science Laboratory, School of Management, University of Massachusetts, Amherst.

Fourth, you would be wise to check the JOURNAL OF THE AMERICAN DIETETIC ASSOCIATION and the AMERICAN JOURNAL OF CLINICAL NUTRITION for articles on iron bioavailability. Several important articles have been published over the past ten years.

Sincerely yours,

Elaine R. Monsen

Elaine R. Monsen, PhD, RD
Professor of Nutrition and Medicine

Telephone: (206) 543-1730