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PREVENTING IRON DEFICIENCY ANEMIA: COMMUNICATION STRATEGIES TO PROMOTE IRON NUTRITION FOR AT-RISK INFANTS IN NORTHERN QUEBEC

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ABSTRACT

A sustainable primary prevention strategy for infant iron deficiency anemia (IDA) was implemented and evaluated in a community with at-risk infants in northern Quebec, Canada. Communication strategies were used to promote iron-rich complementary food rather than iron-fortified formula, which can interfere with breastfeeding practice. This food-based approach has been successfully implemented in developing countries, but has not been applied in an industrialized country setting.

Mass media (i.e., radio dialogues, key messages, print material, point-of-purchase grocery store display) and interpersonal (i.e., homemade baby food cooking activity) communication strategies were developed in collaboration with community members and implemented in partnership with an existing community program. Reach and exposure of the strategies were measured using a questionnaire administered to a post-intervention sample (n=45). Sales of promoted iron-rich infant food were examined pre- and post-intervention period. A repeat cross-sectional design was used for the impact evaluation. Two groups of mothers with infants, aged 7-10 months at Time 1 (n=32) and Time 2 (n=22) were interviewed. Outcome variables were infants' total iron and complementary food iron intakes measured by two 24-hour recalls. Secular trends in infants' hemoglobin values and milk type consumption were examined in the study community and two comparison communities.

Multiple communication channels increased awareness of IDA and influenced self-reported use of iron-rich infant food. Iron-rich infant food sales increased from pre- to post-intervention ($p<0.05$). Complementary food intake iron increased between Time 1 (3.2 ± 0.8 mg) and Time 2 (4.4 ± 1.1 mg) ($p<0.05$). The proportion of infants with anemia (hemoglobin<110 g/L) significantly decreased from the period before (37.2%) to during (14.3%) the intervention ($p<0.05$). No significant difference was found for this variable within the comparison communities. The proportion of infants receiving iron-fortified formula in the study community did not differ between Time 1 and Time 2, but increased from Time 1 (55%) to Time 2 (73%) ($p<0.05$) in the comparison communities, indicating an erosion of breastfeeding practice.

These results suggest the effectiveness of communication strategies to improve infant iron nutrition in a community with good access to iron-rich infant food. The potential for this strategy in other communities warrants further investigation.

RÉSUMÉ

Une stratégie de prévention primaire soutenue de l'anémie ferriprive du nourrisson a été mise en oeuvre et évaluée dans une communauté du nord du Québec (Canada) avec des nourrissons à risque. Des stratégies de communication ont été utilisées pour promouvoir des aliments complémentaires riches en fer plutôt que des préparations de lait maternisé enrichies de fer, qui peuvent interférer avec la pratique d'allaitement au sein. Cette approche alimentaire a été mise en œuvre avec succès dans les pays en voie de développement, mais n'a pas encore été appliquée dans le cadre d'un pays industrialisé.

Les stratégies de communication des media publics (ie, émissions de radio, messages clef, matériel imprimé, éventaires d'épicerie) et interpersonnelles (ie, préparations maison d'aliments pour bébé) ont été développée en collaboration avec les membres de la communauté et mises en œuvre de concert avec un programme communautaire préexistant. La portée et l'exposition aux stratégies ont été mesurées grâce à un questionnaire soumis à un échantillon du groupe cible après l'intervention (n=45). Les ventes d'aliments pour nourrissons riches en fer proposés ont été analysées avant et après la période d'intervention. Une analyse transversale répétée a été utilisée pour évaluer l'impact de l'intervention. Deux groupes de mères avec nourrissons âgés de 7 à 10 mois au temps T 1 (n=32) et au temps T 2 (n=22) ont été interrogées. Les variables des résultats étaient l'apport total en fer des nourrissons et les apports alimentaires complémentaires mesurés après un rappel alimentaire de 24 heures. Les taux d'hémoglobine des nourrissons et le type de consommation de lait ont été analysés dans la communauté étudiée et dans deux communautés de comparaison sur une période de 7 ans..

Les différentes voies de communication ont augmenté la sensibilisation à l'anémie ferriprive et influencé la consommation d'aliments pour nourrisson riches en fer. Les ventes d'aliments pour nourrissons riches en fer ont augmenté après la période d'intervention ($p<0,05$). L'apport en fer par aliments complémentaires a augmenté entre le temps T 1 ($3,2 \pm 0,8$ mg) et le temps T 2 ($4,4 \pm 1,1$ mg) ($p<0,05$). La proportion de nourrissons présentant de l'anémie (hémoglobine <110 g/L) a diminuée de manière significative de la période avant l'intervention (37,2 %) à la période d'intervention (14,3 %) ($p<0,05$). Aucune différence significative n'a été établie pour cette variable au sein des communautés de comparaison. La proportion de nourrissons recevant une préparation de lait maternisé enrichie de fer dans la communauté étudiée n'a pas changé entre les temps T 1 et T 2, mais a augmenté du temps T 1 (55 %) au temps T 2 (73 %) ($p<0,05$) dans les communautés de comparaison, indiquant une diminution de la pratique de l'allaitement au sein.

Ces résultats suggèrent l'efficacité des stratégies de communication pour améliorer l'apport en fer dans l'alimentation des nourrissons dans une communauté ayant accès aux aliments enrichis de fer. Le potentiel de cette stratégie dans d'autres communautés justifie des etudes plus approfondies.

CONTRIBUTION OF AUTHORS

The manuscript presented in Chapter 3 was submitted to the *Public Health Nutrition* journal in February 2004 and the manuscript in Chapter 4 was submitted to the *Preventive Medicine* journal in May 2004. The doctoral candidate was the primary author for both manuscripts. She collected data, performed all statistical analyses and made all major data interpretations. Dr. Katherine Gray-Donald provided consultation for statistical analyses and data interpretation. As well, she provided editorial revisions for both manuscripts. Lily Napash provided assistance with data collection, study implementation and interpretation of results. Sophie Mercure and Lucie Leclerc provided assistance with study implementation and interpretation of results. Both manuscripts were reviewed by the authors as well as by the research committee for the Cree Board of Health and Social Services of James Bay.

STATEMENT OF ORIGINALITY

The objectives of this study and the data presented in this thesis represent an original body of research. This is the first study in an industrialized country to evaluate an intervention promoting a food-based approach to improve infant iron nutrition within a community setting. As well, this study provides original data regarding the adequacy of iron intake in a group of infants at risk for IDA, using the recently published Dietary Reference Intakes (DRI) by the Institute of Medicine.

The doctoral candidate was responsible for the design, implementation, and evaluation of this study. Dr. Katherine Gray-Donald, the thesis supervisor, worked with the candidate in formulating the study design. As well, Dr. Gray-Donald provided guidance with statistical analyses and interpretation. The doctoral candidate collected data and was responsible for entering all data, performing the statistical analyses as well as providing major data interpretations. The candidate trained Lily Napash, a local community person, to assist her with dietary and demographic data collection in the study community. Lily Napash, as well as two health professionals, Sophie Mercure and Lucie Leclerc, provided assistance to the candidate in developing and implementing the intervention within the study community.

This research study has provided important evaluative data regarding the potential for a novel approach in the prevention of infant iron deficiency anemia (IDA) in industrialized countries. The approach investigated in this study has challenged conventional preventive measures (i.e., the provision and promotion of iron-fortified formula) widely applied in industrialized countries and has examined an alternative strategy that is supportive of breastfeeding practice. As well, the process used in developing the intervention provided significant insight into the potential for community involvement in public health programming within Aboriginal communities. The results of this study will have relevant applications to similar community settings where a high prevalence of infant IDA is a concern.

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CHAPTER 1. INTRODUCTION

1.1 Background

Over 2 billion people are affected by iron deficiency worldwide, the majority of whom live in developing nations (Ramakrishnan 2002). In the past two decades, an overall decline in iron deficiency anemia (IDA) prevalence has been observed in the North American pediatric population (Sherry et al. 2001; Yip et al. 1987). However, a significant number of infants and young children living in industrialized countries continue to be adversely affected by iron deficiency. High IDA prevalence rates have been found among certain ethnic populations and infants and young children living in disadvantaged environments (Booth & Aukett 1997; Eden & Mir 1997; Lehmann et al. 1992; Oti-boateng et al. 1998; Sawchuk et al. 1998; Willows et al. 2000).

Infancy is one of the most critical periods of growth and development. It is also a period of considerable vulnerability to developing IDA (Yip & Dallman 1996). The requirements of iron, particularly during the latter part of the first year of life, are significant owing to depleted iron stores around 6 months of age and the rapid growth that occurs (Institute of Medicine 2001). Current convincing evidence has shown that IDA in infancy and early childhood is strongly associated with the development of cognitive and psychomotor deficits (Lozoff et al. 1991; Moffatt et al. 1994; Walter et al. 1989). Furthermore, it is unclear if the negative effects of this condition are reversible with iron therapy (Hurtado et al. 1999; Idjradinata & Pollitt 1993; Lozoff et al. 1996; Lozoff et al. 2000).

Although there are multi-factorial causes of infant IDA, inadequate iron intake has been considered the primary cause in industrialized countries (Lesperance et al. 2003). Early introduction of unmodified cow's milk, duration of breastfeeding, and inadequate intake of iron-rich complementary food have been associated with poor iron status (Calvo et al. 1992; Dewey et al. 1998; Friel et al. 1999; Greene-Finestone et al. 1991; Innis et al. 1997; Lehmann et al. 1992; Pisacane et al. 1995; Pizarro et al. 1991; Sadowitz & Oski 1983; Siimes et al. 1984). However, factors associated with inadequate iron intake are important such as a caregiver's ability to provide optimal iron nutrition as well as the environment where a caregiver and infant live (Pollitt 2001).

There are three principal strategies for preventing IDA: iron supplementation, iron-fortification, or a food-based approach where the bioavailability and access to local iron rich food are improved through promotional activities (Zlotkin 2003). In countries where there are clusters of mild to moderate IDA prevalence among the population, the use of iron fortified food and food-based approaches are recommended (Howson et al. 1998). The basis of infant IDA prevention in industrialized countries has been the provision and promotion of iron-fortified formula and infant food (Ramakrishnan & Yip 2002). Both the efficacy and effectiveness of iron-fortified formula in preventing infant IDA has been shown (Daly et al. 1996; Moffatt et al. 1994; Sawchuk et al. 1998). Unfortunately, the "success" of this prevention strategy has occurred at the expense of breastfeeding practice, which is considered the optimal milk nutrition for infants (Ponza et al. 2004). In view of these findings and the considerable magnitude of this public health problem among identified pediatric groups, research is warranted to identify appropriate primary prevention strategies. A detailed review of the importance of infant iron nutrition, the magnitude of infant IDA prevalence in industrialized countries as well as an examination of prevention strategies is found in chapter 2.

In 2000, a high prevalence of ID and IDA was found among 9-month-old infants living in the James Bay region of northern Quebec, Canada (Willows et al. 2000). This region is home to approximately 12,000 Cree First Nations people living in nine communities. In response to the magnitude of this health problem affecting infants from these communities, the candidate proposed a study to investigate a relevant IDA prevention strategy. Data were limited regarding the iron adequacy of the diets of these infants. However, a low intake of meat had previously been found among infants (Willows & Gray-Donald 2002). Within the Cree communities, there is a strong tradition of breastfeeding, particularly among women living in coastal versus inland communities. As well, the traditional diet of the James Bay Cree First Nations consists of iron-rich wild meat such as goose, caribou and moose. The candidate hypothesized that the use of a food-based approach to promote optimal iron nutrition of these infants would be appropriate, given that this strategy could be adapted to different cultural settings, would be supportive of breastfeeding and could promote the iron-rich traditional and market infant food available in the communities (Food and Agriculture Organization of the United Nations 1997). The Cree Board of Health and Social Services of James Bay (CBHSSJB) agreed to this study proposal and an appropriate study community was identified in the region. A research agreement was prepared with McGill University, the CBHSSJB, and the Cree nation of Chisasibi. As well, ethical approval was obtained from the McGill Ethics Committee (appendix a).

To enhance sustainability, the intervention was implemented in collaboration with an existing nutrition program (i.e., Canada Prenatal Nutrition Program—CPNP) within the study community. As well, a local community person was hired and trained to assist with data collection, planning and implementation. In the summer of 2001, the needs assessment and initial planning for this study were conducted. Subsequently, development of the intervention activities was undertaken in collaboration with interested community members. A local artist was hired to prepare artwork for intervention, based on the ideas provided by community participants. Implementation of the intervention subsequently began in the summer of 2002. The process evaluation measured the effectiveness of the intervention activities and was conducted throughout the implementation phase, as well as 6 months after the intervention had begun. Chapter 3 presents the results of this evaluation as well as the conceptual information regarding the intervention activities. The impact of the evaluation measured the change in dietary behaviour (i.e., infant iron intake) and was assessed prior to and 6 months after the beginning of the intervention. The results of this evaluation, including an assessment of the infants' dietary iron adequacy, are found in chapter 4. The final chapter of this thesis examines the significance of food-based approaches in decreasing iron deficiency, the essential elements that contribute the success of this strategy, and suggestions for future research to further an understanding of the potential for this strategy.

1.2 Research objectives

The aim of this study was to develop, implement and evaluate the effectiveness of a food-based approach for improving infant iron nutrition within a community with infants at-risk for IDA. Specifically, the research objectives were to:

1) Examine infant caregivers' understanding and perceptions of IDA and the health of their child.
2) Identify factors that may facilitate or constrain adequate infant iron nutrition.
3) Examine the feasibility of community collaboration in developing relevant and appropriate communication strategies to promote locally available iron-rich infant food.
4) Measure the effectiveness and acceptability of various communication strategies to promote iron-rich infant food in the community.
5) Among infants 7-10 months of age, measure changes in dietary iron intake and estimate the prevalence of inadequate iron intake pre- and post-intervention to evaluate the impact of the intervention.

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CHAPTER 2. LITERATURE REVIEW

Chapter 2 presents a review of the literature pertaining to the public health issue of ID and IDA among certain vulnerable pediatric groups from industrialized countries. Background information regarding iron function, metabolism and requirements in infancy is discussed. The magnitude of this health issue is examined including a review of prevalence rates, the adequacy of infant iron intake and adverse outcomes. An overview of risk factors for infant ID and IDA is presented, with a detailed review of dietary factors. The final section of the literature review explores current population-based prevention strategies for infant ID and IDA implemented in industrialized countries. A critique of these primary prevention strategies is presented and novel strategies, used in developing countries, are reviewed to investigate their potential for application in industrialized countries.

2.1 Iron nutrition in infancy

(a) Iron function and distribution

In biological systems, iron exists in the ferrous (Fe^{2+}), ferric (Fe^{3+}), or ferryl (Fe^{4+}) states. Conversion of these oxidation states allows iron to participate in electron transfer and reversibly bind ligands such as oxygen, nitrogen and sulfur atoms (Institute of Medicine 2001a)—making this nutrient necessary for a large number of biochemical reactions (Beard et al. 1996). There are four major classes of iron-containing proteins that exist in the human body, iron-containing heme proteins (i.e., hemoglobin, myogoblin, cytochromes), iron-sulfur enzymes (i.e., hemeflavoproteins, flavoproteins), iron-containing proteins for storage and transport (i.e., transferrin, lactoferrin, ferritin, hemosiderin), and other iron-containing or activated enzymes (i.e., sulfur, non-heme enzymes (Institute of Medicine 2001a). These iron-containing proteins function as either essential compounds involved in metabolic or enzymatic functions or storage compounds involved in the regulation of iron homeostasis (Dallman 1989).

The important essential iron compounds are hemoglobin, myoglobin and cytochromes. Hemoglobin is found in circulating erythrocytes and contains more than 65% of total body iron (Boccio et al. 2003). Its principal function is to carry oxygen from the lungs to the remaining body tissues (Boccio et al. 2003). Myoglobin, located in the cytoplasm of muscle cells, contains approximately 10% of total body iron. Its principal role is to increase the rate of oxygen diffusion from capillary erythrocytes to the cytoplasm and mitochondria (Institute of Medicine 2001a). Cytochromes are heme-containing enzymes found primarily in the mitochondria of aerobic cells. These enzymes act as electron carriers in the electron transport chain, producing cellular energy in the form of adenosine triphosphate (ATP) (Boccio et al. 2003). Iron also serves as a key component of the enzyme ribonucleotide reductase, which is involved in the rate-limiting step for DNA synthesis (Beard et al. 1996). Cytochromes and the other iron-containing enzymes represent only 3% of total body iron (Dallman 1989). However, the presence of these enzymes is physiologically critical, because the absence of iron will result in their inactivity (Boccio et al. 2003).

The primary storage protein is ferritin, 60% of which is located in the liver and 40% of which is found in the cells of the reticuloendothelial system or muscle tissues (Boccio et al. 2003). Ferritin production increases when the supply of iron exceeds the cell's functional needs (Institute of Medicine 2001a). Ferritin has the capacity to hold large amounts of iron per molecule; however, it is most efficient in acquiring and releasing iron when it is 20% saturated (Beard et al. 1996). Hemosiderin is a water-insoluble degradation product of ferritin, formed when the ferritin molecule has become saturated with iron. This storage protein contains less chemically reactive iron and is, therefore, less available for iron mobilization (Beard et al. 1996).

The distribution of iron containing compounds in the healthy term infant is summarized in Figure 2-1. At birth, the infant has an average of 75 mg of iron per kilogram of body weight, which is almost twice that of an adult man (Fairweather-Tait 1992; Faldella et al. 2003). The majority of iron content is found in circulating hemoglobin (Fairweather-Tait 1992). As well, the healthy term infant is born with generous iron stores that provide for synthesis of essential iron compounds. These iron stores are supplemented by iron made available from the breakdown of hemoglobin, as

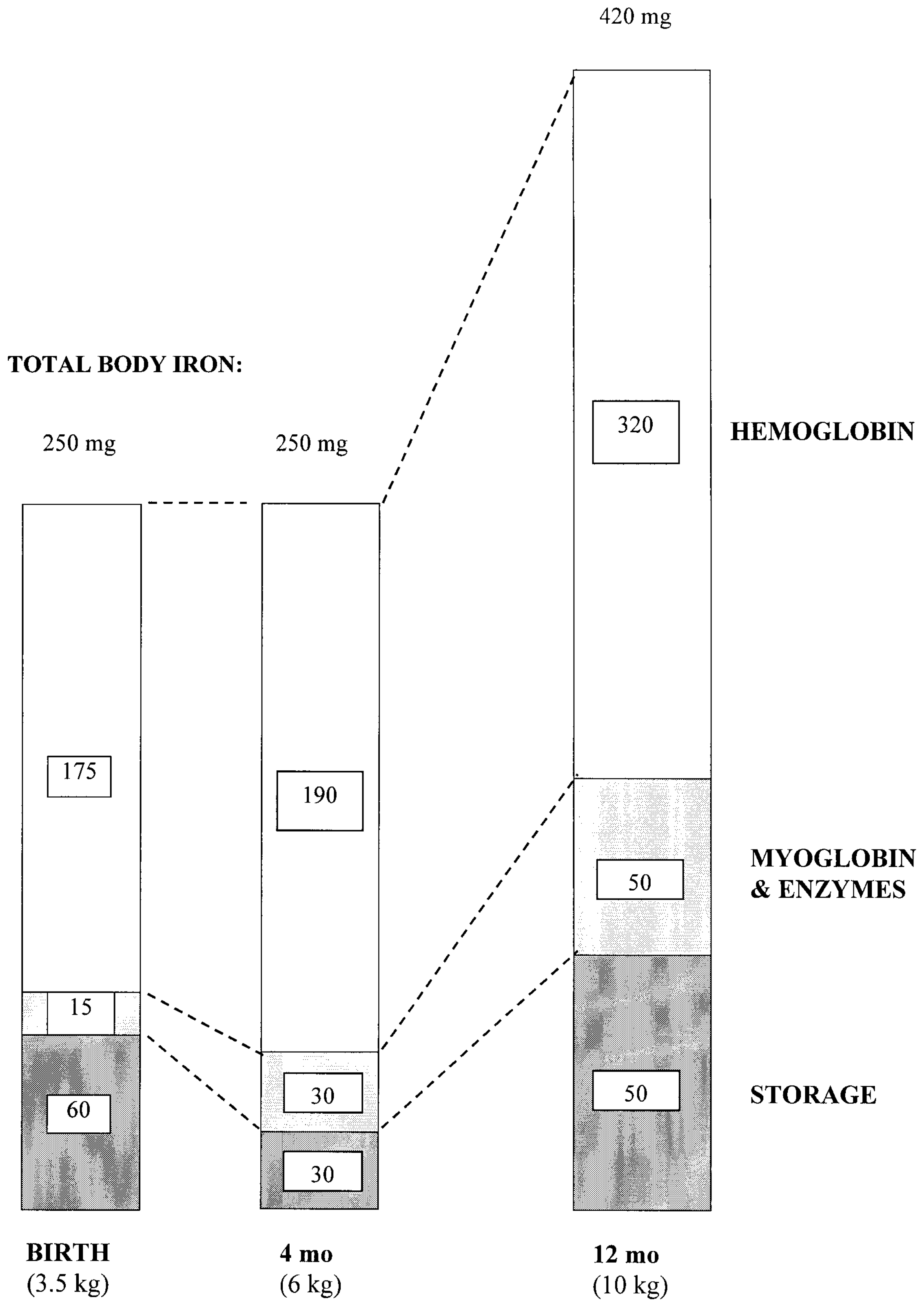

Figure 2-1 Body iron distribution during first year of life From Dallman 1993.

hemoglobin concentration declines from a mean of 170 g/L at birth to approximately 110 g/L at 2 to 3 months of age (Dallman 1989). Thus, the infant's need for exogenous iron is relatively minimal during this time (Dallman 1989).

Around 4 to 6 months of age, the infant begins a period of rapid growth, tripling his or her birth weight by 12 months of age (Oski 1989). Total body iron increases from 250 mg to approximately 420 mg at 12 months, with 50% of this increase occurring in total hemoglobin concentration (Dallman 1989; Wharton 1999). It is during this period, that the infant becomes highly dependent on exogenous iron and is, therefore, most vulnerable to deficiency (Dallman 1989).

(b) Iron metabolism

An overview of iron metabolism is presented in Figure 2-2. Intake, storage and loss are the three main factors affecting iron metabolism and balance (Yip & Dallman 1996). The majority of iron absorption occurs in the duodenum and upper jejunum (Beard et al. 1996). Current knowledge is incomplete regarding the specific mechanisms for iron absorption (Beard et al. 1996). However, different pathways are believed to exist for the absorption of non-heme and heme iron (Yip & Dallman 1996). Non-heme iron is made soluble by gastric acid and pancreatic proteases. It must be must be bound to intraluminal iron-binding molecules for stabilization within the alkaline environment of the intestine (Beard et al. 1996). Heme iron remains soluble in an alkaline environment and, therefore, does not require these binding proteins for absorption (Beard et al. 1996). As well, heme iron is absorbed two to three times more efficiently than non-heme iron (Yip & Dallman 1996).

Specific transporters exist on the luminal surface of enterocytes for non-heme binding proteins. However, specific transporters/receptors for heme iron have not been identified in humans (Beard et al. 1996). Both heme and non-heme iron are transported within the interior of the enterocyte bound to a transferrin-like protein. In response to increased iron requirements, iron is transported to the basolateral membrane, oxidized to its ferric form and then attached to the plasma transport protein called transferrin

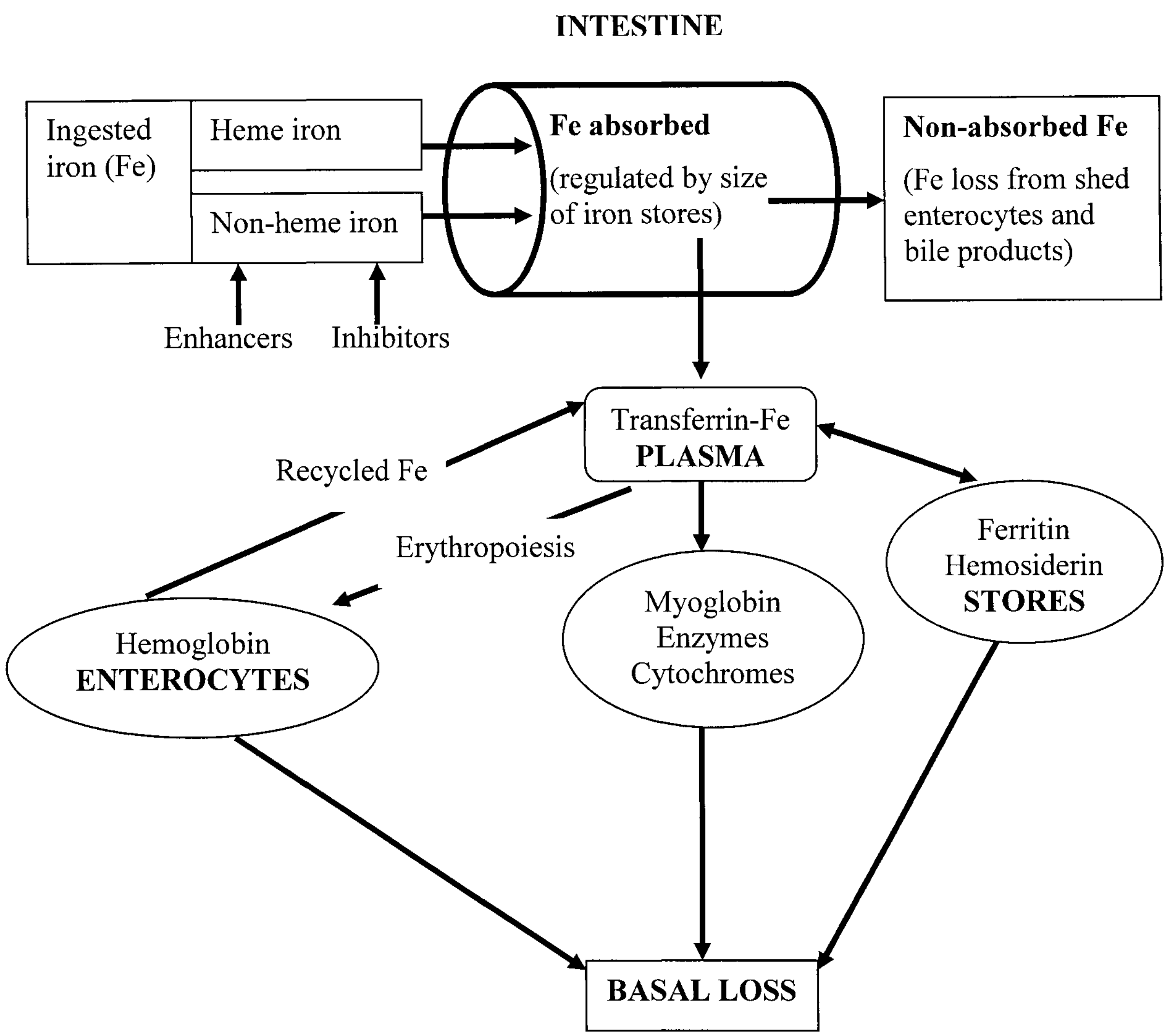

Figure 2-2 Overview of iron metabolism
Adapted from Boccio et al. 2003; Michaelsen et al. 2000.

(Yip & Dallman 1996). Transferrin delivers iron to the tissues via specific transferrin-receptors located on the cell membrane (Yip & Dallman 1996). The number of receptors located on cells is highly regulated and will increase in response to cell iron depletion or decrease with abundant iron supply (Yip & Dallman 1996). Iron, not used for physiological functions, is stored primarily in cells of the liver, bone marrow and spleen (Yip & Dallman 1996). Overall, basal losses of iron are small. Unabsorbed iron is eliminated in the feces, along with iron from desquamated enterocytes and bile (Yip & Dallman 1996). Smaller amounts of iron are lost through skin cells and urine (Yip & Dallman 1996).

Iron homeostasis has two distinct features. Unlike other trace minerals, iron balance is maintained primarily through iron absorption rather than through excretion or elimination. The control of iron absorption is thought occur with three independent regulators: intestinal response to iron storage levels, intestinal response to iron requirements for erythropoiesis, and by the influence of recent dietary intake (e.g., amount and bioavailabiltiy of dietary iron) (Leong & Lonnerdal 2004). Knowledge of how iron status and erythropoietic demand are communicated to the intestine has recently been advanced. The expression of a substance called hepcidin has been shown to increase in iron overload and decrease in iron depletion, suggesting a role in iron absorption regulation (Leong & Lonnerdal 2004). In older infants, Domellof et al. (2002b) have suggested that developmental changes occur in iron absorption regulation that may enhance the infant's ability to adapt to a low-iron diet. Other researchers have found that iron absorption in the first year of life increases with age (Fomon et al. 2000).

A second distinct feature of iron balance is the body's ability to conserve iron through a mechanism that recycles iron from the hemoglobin of senescent erythrocytes. Iron liberated through the degradation of old red blood cells is rapidly released into the plasma attached to transferrin and transported to bone marrow for incorporation into erythrocyte biosynthesis (Boccio et al. 2003).

A significant difference between iron homeostasis in infants compared to adults is the degree of dependence on exogenous iron (Figure 2-3). An adult male requires only 5% of iron from dietary sources, as about 95% of iron requirements are met through recycled iron from the breakdown of old red cells. Conversely, a year-old infant derives less than 70% of iron from senescent red cells and therefore, requires about 30% from the diet to meet the needs imposed by rapid growth. As a result, infants are more dependent on dietary iron to meet their iron requirements, as they must absorb an amount of iron several times greater than their iron losses (Dallman 1988).

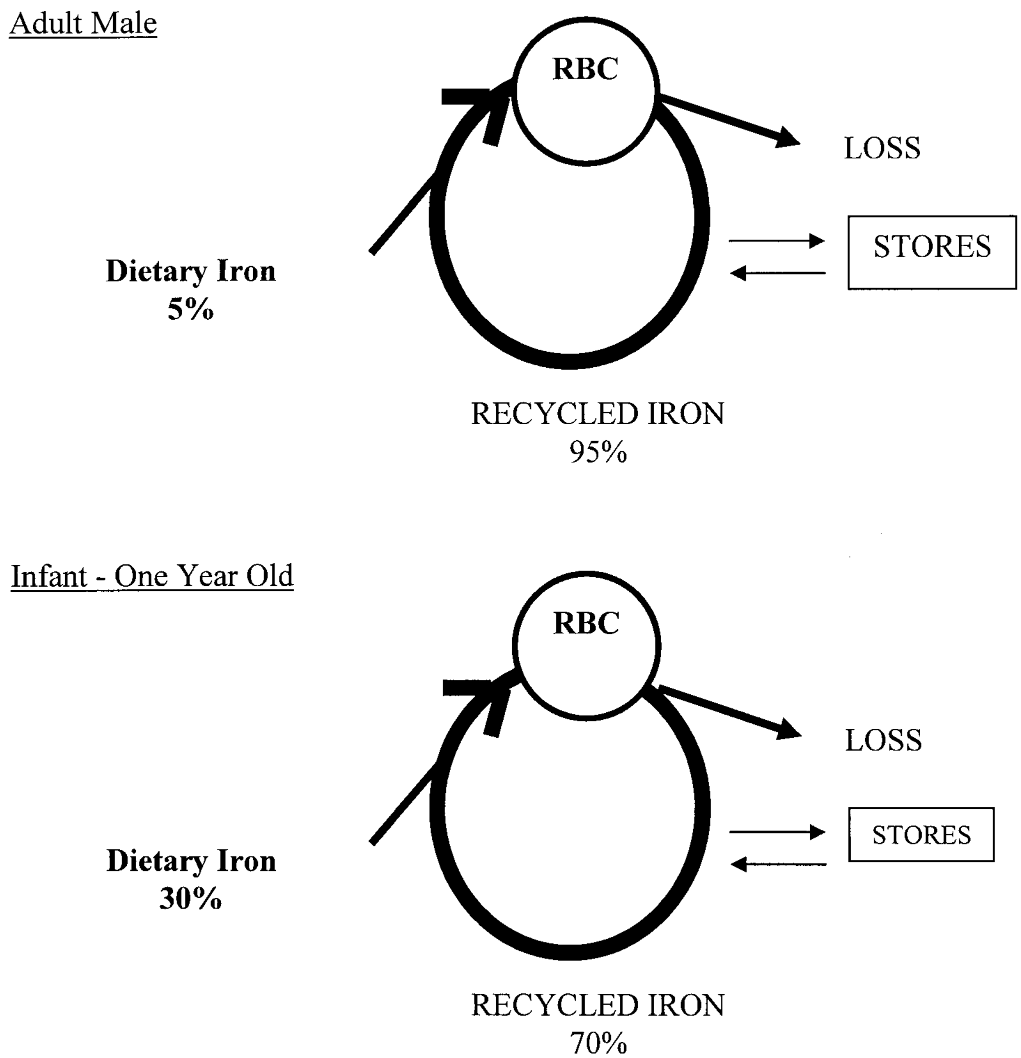

Figure 2-3 Differences in iron homeostasis between the infant and adult male
From Dallman 1988.

(c) Iron requirements in infancy

Iron endowment at birth, rate of growth, iron content and composition of the diet as well as physiological loss determine iron requirements in the first year of life (Oski 1989). During gestation, iron is transported unidirectionally from the mother to the fetus against a concentration gradient (Oski 1989). The placenta successfully competes with maternal erythroid marrow for circulating transferrin (Oski 1989). The iron is then transported across the placenta where is attaches to transferrin in the fetal circulation (Oski 1989). Iron is accumulated in the fetus throughout gestation, with the greatest accumulation occurring during the last trimester (Siimes 1990). The fetus accrues iron in amounts proportional to increasing gestational age and weight (Oski 1989). Thus, lower iron stores are found in pre-term infants and/or those born with a lower birth weight (Oski 1989). Other important factors that may decrease iron stores at birth include perinatal blood loss, delayed umbilical cord clamping—decreasing hemoglobin mass and the occurrence of fetal to maternal hemorrahge (Oski 1989).

For the first 4 to 6 months of life, iron stores of the healthy, term infant are adequate to meet requirements for growth. However, around 6 months of life iron stores become depleted and the infant begins to grow rapidly, influencing exogenous iron requirements (Oski 1989). Evidence of an association between growth velocity and iron stores has been shown in term infants of normal birth weight. A greater rate of growth has been associated with an increased risk for depleted iron stores in the latter part of the first year of life (Male et al. 2001; Michaelsen et al. 1995; Sherriff et al. 1999; Thorsdottir et al. 2003). In contrast to iron requirements imposed by growth rate, a relatively small amount of iron is required to replace basal iron loss (Oski 1989).

The total amount of dietary iron intake needed to meet infant iron requirements depends on the bioavailability the diet (Brown et al. 1998) (Table 2-1). The type of iron consumed, heme or non-heme, and the presence of other food constituents that can either enhance or inhibit iron absorption determines bioavailability (Table 2-2). Heme iron, supplied mainly in meat, fish, or poultry, makes up only 10-15% of dietary iron (Yip & Dallman 1996). However, the bioavailability of this form of iron is around 25% and absorption is only slightly affected by the presence of other food constituents (Brown et al. 1998). Non-heme iron comprises the greatest component of dietary iron (85%) (Yip & Dallman 1996). However, absorption of this form of iron is highly variable depending on the composition of the meal, including the presence of inhibiting or enhancing absorption factors. Thus, iron absorption from such a meal may vary from 1 to 40% in individuals who have similar iron stores (Food and Agriculture Organization of the United Nations 1988).

Table 2-1 Bioavailability categories of meals

Bioavailability Level[2]	Description of diet	% Iron absorption[1]
Low bioavailability	▪ Cereals (maize, whole wheat flour and sorghum), legumes, roots and/or tubers ▪ Negligible quantities of animal source food and/or ascorbic acid	5
Intermediate bioavailability	▪ Cereals, roots, and/or tubers ▪ Negligible quantities of animal source food and/or ascorbic acid	10
High bioavailability	▪ Diversified diet with generous quantities of animal source food and high amounts of ascorbic acid	15

From Brown et al. 1998; Food and Agriculture Organization of the United Nations 1988.
[1]Assuming absorption of individual with no iron stores, but not anemic.
[2]A high bioavailability diet can be reduced to an intermediate bioavailability diet by regularly consuming meal with higher amount of inhibitors.

Table 2-2 Summary of factors influencing dietary iron absorption

Heme iron absorption

- Iron status of individual
- Amount of heme iron consumed (especially as meat)
- Content of calcium in meal
- Food preparation, time and temperature

Non-heme absorption

- Iron status of individual
- Amount of potentially available non-heme iron
- Balance between enhancing and inhibiting factors:
  Inhibiting factors:
    - Phytates and other inositol phosphates (e.g., legumes, rice, grain)
    - Phenolic compounds – e.g., tannins in tea
    - Calcium
    - Soy proteins

  Enhancing factors:
    - Ascorbic acid
    - Meat, fish, poultry
    - Some fermented vegetable and soy sauces

From Hallberg & Hulthen 2002.

A highly bioavailable diet is considered typical for most segments of the populations in industrialized countries (Food and Agriculture Organization of the United Nations 1988) and researchers have proposed that the bioavailability in a mixed American or Canadian diet may be as high as 18% (Institute of Medicine 2001a). However, the diets of older infants contain little animal source food and are rich in cereals and vegetables. Therefore, the bioavailability of older infants' diets is estimated to be 10% (Institute of Medicine 2001a).

(d) Dietary iron recommendations

Recommendations for iron intake have evolved over the past two decades. Previous to 2001, separate recommendations for nutrient intake existed for Canada (Recommended Nutrient Intake—RNI) and the United States (Recommended Dietary Allowances—RDA). However, more recently scientists from both countries have collaborated to derive a comprehensive set of nutrient "reference values" for healthy populations (Dietary Reference Intakes—DRI) (Institute of Medicine 2001a) (Table 2-3). In all instances, dietary iron recommendations during infancy have been determined by estimating the required amount of absorbed iron based on factorial modeling and then applying a percentage of iron bioavailability in the diet (Institute of Medicine 2001a). Distribution of the components for absorbed iron requirements (basal losses, growth accretion and stores) are modeled on the basis of known physiology (Institute of Medicine 2001a). The total need for absorbed iron is then estimated by the sum of these component requirements (Institute of Medicine 2001a).

Given that the requirement for exogenous iron of a healthy term infant is negligible, the recommended iron intake for early infancy is based on the amount of iron consumed by healthy, term infants exclusively breastfed by well-nourished mothers or 0.27 mg/day (Health Canada 1990; Institute of Medicine 2001a; Subcommittee on the Tenth Edition of the RDAs 1989). In this calculation, the iron content of breast milk was estimated to be 0.35 mg/L and breast milk intake was estimated to be 0.78 L/day, based on current data from the literature (Institute of Medicine 2001a). The current reference value represents an "adequate intake", which assumes that the measured intakes were adequate to meet the

Table 2-3 Comparison of North American recommended iron intakes in infancy: RDA, RNI and DRI

Reference value	Age - months	Weight (kg)	Obligatory or basal iron loss (mg/day)	Iron accretion: growth + stores (mg/day)	Total requirement absorbed iron (mg/day)	Recommended dietary intake (mg/day)
RNI[a]	0-4	6	0.24	0	0.24	0.26
RDA[b]	0-5	6	No value specified	No value specified	No value specified	6 (1 mg/kg/day)
DRI[c] (AI[d])	0-6	No value specified	No value specified	0	No value specified	0.26
RNI[a]	5-12	9	0.37	0.34	0.7[g]	7[h]
RDA[b]	6-12	9	No value specified	No value specified	No value specified	10
DRI[c] (EAR[e])	7-12	8.7	0.26	0.43	0.69 (median)	6.9[h]
DRI[c] (RDA[f])	7-12	8.7	0.26	0.43	1.07 (97.5^{th} percentile)	11[h]

From Health Canada 1990; Institute of Medicine 2001a; Subcommittee on the Tenth Edition of the RDAs 1989.
[a]Recommended nutrient intake
[b]Recommended dietary allowances
[c]Dietary reference intakes
[d]Adequate intake
[e]Estimated average requirement
[f]Recommended dietary allowances as a dietary reference intake
[g]Assuming 15% coefficient of variation and 2 standard deviations (30%)
[h]Assuming 10% iron bioavailability from diet

iron requirements of the populations studied and that the study samples were representative (Institute of Medicine 2001a). As well, no consideration was given to the specific needs of formula-fed infants (Institute of Medicine 2001a). There may be differences in dietary requirements between infants who are exclusively breast-fed and those who are fed formula, because of differences in the efficiency of nutrient utilisation between these two milk types (Aggett et al. 1997). Thus, the iron intake of breast-fed infants may not be an adequate reference model for babies who are not exclusively breast-fed (Aggett et al. 1997). In comparison, previous RDA values did allow for lower bioavailability of nutrients from nonhuman milk.

The value for total requirement of absorbed iron during the latter part of infancy is similar in comparing the RNI, RDA and recent DRI values. However, there are differences in the theoretical estimates for iron accretion and obligatory losses among the recommended values and reflect, in part, different interpretations of the data and a greater consideration of individual variability in iron requirements with the latest recommended values (Pasut 2002). Earlier iron recommendations were derived using the mean values for growth and obligatory losses assuming a 15% coefficient of variation plus two standard deviations (Health Canada 1990; Subcommittee on the Tenth Edition of the RDAs 1989). The current recommended iron values were calculated using the median (50^{th} percentile) absorbed iron requirement to derive the EAR and the 97.5th percentile to derive the RDA (Institute of Medicine 2001a). In both instances, the recommended intake value was calculated assuming 10% iron bioavailability.

Interpretation of dietary reference values has changed from earlier recommendations. With the previous RDA and RNI, the probability of inadequacy for usual nutrient intake could not be calculated, because the distributions of requirements were not described (Murphy et al. 2002). With DRI values, the distributions of requirements for most nutrients are presented and, therefore, the probability of inadequacy can be calculated by comparing the distribution of usual intakes with the distribution of requirements (Institute of Medicine 2000). Importantly, to derive this estimate, the observed intakes for each individual must be adjusted for within-person variability to arrive at the usual intake distribution of the group. Large variances are almost always found with distributions of observed intakes, due to both within and between person variations (Institute of Medicine 2000). Thus, using distributions of observed intakes (without adjustment) can lead to incorrect estimates of the prevalence of nutrient inadequacy (Barr et al. 2002; Institute of Medicine 2000).

A statistical method has been developed by the (National Research Council 1986) to partially remove the within-person variation by fitting a measurement error model to daily intake data. For this method, at least 2 days of independent dietary recall data are required from a representative sub-sample to provide an estimate of the day-to-day variation for the group. The observed intakes may need to be transformed to ensure normality. Then, the difference between each individual's intake and the mean intake of the group is multiplied by the ratio of within variation to the total variation and added back to the mean intake for the group (Institute of Medicine 2000). The adjusted intakes are transformed back to the original scale (Institute of Medicine 2000). The usual nutrient intake distribution is then compared to the distribution of the nutrient requirement.

For most nutrients, requirement distributions are symmetrical. Therefore, it is not necessary to know the actual variance of the requirement distribution to calculate the prevalence of inadequate nutrient intake for a group (Institute of Medicine 2000). In this situation, the proportion of a population with usual intakes above the EAR, but below their individual requirements (group A) is approximately equal to the proportion of a population with usual intakes below the EAR, but above their own individual requirements (group B) (Institute of Medicine 2000). Thus, group B can be "substituted" for group A and the prevalence of inadequacy is simply those individuals with usual intakes below the EAR; knowledge of the distribution of nutrient requirements is not needed (Institute of Medicine 2000). However, for iron, the distribution for requirements is not normally distributed. Therefore, calculations involving a full probability approach are required. For infants and children, a table of the probability of iron inadequacy at various intakes has been derived from data from the Continuing Survey of Food Intakes by Individuals (CSFII) survey (Institute of Medicine 2001b). Using the data from this table, usual iron intake data (adjusted intake) can be compared and the risk of inadequacy for each individual in the group can be calculated. The average of the individual probabilities is then calculated (Institute of Medicine 2001b). The ability to assess the prevalence of a nutrient inadequacy in a group has important implications from a public health perspective. An unacceptably high prevalence of inadequate intake may warrant an intervention to increase nutrient intake (Murphy et al. 2002).

In addition to recommended values for iron intake, specific nutrition recommendations have been devised to guide optimal infant iron nutrition. In Canada, these recommendations include breastfeeding until up to 2 years of age and beyond with exclusive breastfeeding until 6 months of age, iron-fortified formula for infants not receiving breast milk or who are receiving formula as well as breast milk, an adequate source of iron-rich complementary food (including iron-fortified cereal) starting at 6 months; and delaying the introduction of cow's milk until 9 to 12 months of age—as cow's milk has poor iron content and has been associated with intestinal blood loss in early infancy (Canadian Paediatric Society 2003).

(e) Iron food sources: amount and bioavailability

During the period from 6 months to 2 years, the sources of iron in the infant diet change from a diet of only infant formula or breast milk to a more complex diet consisting of a variety of complementary food. The amount and bioavailability of iron in complementary food varies considerably. It is the combination of poor iron status, rapid growth and varied iron content/bioavailability that places infants and toddlers at particular risk for iron deficiency. Adequate iron intake from infant food and, thus, feeding practices are critical to maintaining optimal iron nutrition (Dallman 1993).

(i) Human milk

The average iron content of human milk is approximately 0.35 mg/L, but varies considerably with the period of lactation (Institute of Medicine 2001a). Values ranging from 0.4–0.8 mg/L have been found in early lactation (i.e., colostrum and transitional milk), decreasing to 0.2 – 0.4 mg/L in mature milk (Fomon 1993; Lonnerdal 1997; Silvestre et al. 2001). The whey fraction of human milk contains the most iron (58%), with half of this iron bound to proteins such as lactoferrin or associated with citrate (Lonnerdal 1997). Approximately 33% of iron is associated with human milk lipids and only 9% is bound to the casein fraction (Lonnerdal 1997).

Human milk iron concentration does not appear to be associated with maternal iron status (Domellof et al. 2004), nor related to maternal dietary iron intake or supplementation (Lonnerdal 1986; Siimes et al. 1984). Therefore, it has been suggested that iron content of human milk is under homeostatic control with regulated control of iron transport through the mammary glands (Domellof et al. 2004).

Although the iron content of human milk is low, the iron absorption from this milk type has been shown to be as high as 49% in exclusively breastfed infants, aged 6-7 months (Saarinen et al. 1977). The low content of iron and iron absorption inhibitors have been suggested to explain, in part, the high iron bioavailability of human milk (Fomon 1993). Iron absorption has been shown to increase with lower iron content of the diet (Hernell & Lonnerdal 2002). As well, the high concentration of lactoferrin in human milk appears to have a significant role. A receptor specific for human lactoferrin has been identified and is believed to facilitate iron absorption in the brush border of the intestine (Fomon 1993). However, more recent stable isotope studies have measured erythrocyte incorporation of iron among breastfed infants and reported lower fractional absorption values ranging from 12–25 % (Abrams et al. 1997; Davidsson et al. 2000; Domellof et al. 2004). These more recent studies reflect iron absorption of human milk among breast fed infants consuming a variety of complementary solid food.

The overall amount of iron absorbed from human milk is less than the requirements for absorbed iron, particularly among older infants—even though this milk type is highly bioavailable. Assuming an average breast milk intake of 0.6 L/day for infants 7-12 months and an average iron content of 0.35 mg/L of breast milk, only 0.21 mg of iron would be consumed per day (Institute of Medicine 2001a). If the maximum absorption of 50% were assumed, then only 0.11 mg of iron/day would be absorbed. This absorbed iron intake would only provide 16% of the estimated absorbed iron requirement of 0.69 mg/day for infants 7-12 months (Institute of Medicine 2001a). Studies examining the adequacy of iron status among exclusive breastfed infants have shown that breast milk provides adequate iron for at least the first 6 months of age (Calvo et al. 1992; Dewey et al. 1998; Siimes et al. 1984). Poor iron status has been shown among infants exclusively breastfed for longer duration (i.e., past 6 months of age). Exclusively breastfed infants were shown to have low iron stores at 9 months of age (Calvo et al. 1992; Pizarro et al. 1991). As well, Lonnerdal & Hernell (1994) found that 6-month-old exclusively breast-fed infants had higher serum transferrin receptor levels, which are an indicator of cellular iron need, in comparison to iron-fortified formula fed infants of the same age.

(ii) Infant formula

Infant formula is based on either cow's milk (i.e., regular or iron-fortified formula) or isolated soy protein (i.e., soy formula) and the nutrient composition is manufactured to resemble that of human milk (Lynch & Hurrell 1990). However, formula does not contain components such as lactoferrin and immunoglobulins, which are found in human milk (Lynch & Hurrell 1990). Infant formula is fortified with ferrous sulfate, a highly water-soluble iron compound that is more readily absorbed than other iron compounds used in iron fortification (e.g., ferric pyrophosphate, elemental iron powders) (Hurrell 2002). Ferrous sulfate is used as a reference level from which to compare the absorption and utilization of all other fortification iron (Lynch & Hurrell 1990). Iron fortification levels of infant formula in North America vary from 1.5 mg/L (regular formula) to 12 mg/L (iron-fortified and soy formula).

The absorption of iron from formula has been shown to be inversely proportional to the iron content of the formula (Fomon et al. 1997; Saarinen & Siimes 1977). Absorption from low iron formula (1.5 mg/L) has been found to range from 8-11% (Davidsson et al. 2000) compared to only 3-5% for iron-fortified formula (12 mg/L) (Fomon et al. 1997; Rios et al. 1975). A study recently conducted by Hertrampf et al. (1998) used isotopically labelled iron to measure the iron bioavailability of several infant formulas in adult women. The iron content of the tested formulas ranged from 7 to 12 mg/L. The researchers reported an average absorption of 19% from these formulas and attributed this higher value to new modifications in current infant formulas that may improve absorption (e.g., milder heat treatment of the formula that results in higher vitamin C levels). Vitamin C has been demonstrated to enhance iron absorption from infant formula (Stekel et al. 1986).

The absorption of iron from isolated soy-protein formula is thought to be low due to the inhibitory effects of soy on non-heme iron absorption and iron fortificants (Lynch & Hurrell 1990). Hertrampf et al. (1986) found that iron absorption from soy formula was only 1.7% among 16 adult women. However, the adequacy of soy formula in maintaining iron status of 9-month-old infants was found to be comparable to the adequacy of iron-fortified formula. Among 9-month-old infants who received formula and complementary food from 4 months of age, anemia was found in only 4.3% soy formula fed and 2.2% iron-fortified formula fed infants (Hertrampf et al. 1986). Studies have also reported a protective effect of iron-fortified cow's milk-based formula consumption on the iron status of the infant (Bradley et al. 1993; Haschke et al. 1993; Pizarro et al. 1991).

More recently, researchers have questioned the level of iron fortification in infant formula, particularly for infants younger than 6 months of age. Hernell & Lonnerdal (2002) found no significant differences in hematological variables between two groups of 6 months old infants who had been fed either formula with 1.6 mg iron/L or formula with 4 mg iron/L since 1 month of age. These same researchers had previously shown no significant differences between the hematological status of 6-month-old infants who had been fed iron-fortified cow's milk-based formula containing 4 mg of iron/L or 7 mg of iron/L (Lonnerdal & Hernell 1994). Similarly, no significant differences were found in the iron status of infants at 6 or 9 months of age who had been fed formula fortified with 3 mg of iron/L or 6 mg of iron/L (Haschke et al. 1993). Assuming a daily formula consumption of at least 750 ml for younger infants, currently available iron-fortified formula would provide 9 mg of iron per day. If 19% absorption were considered, 1.7 mg of absorbed iron would be provided per day. Current DRI recommendations suggest that and "adequate intake" for this age group is 0.27 mg/day, based on the amount of iron provided in human milk (Institute of Medicine 2001a). Thus, iron-fortified formula would provide six times more iron than recommended. Together, these data suggest that the current level of iron in iron-fortified cow's milk-based and isolated soy protein infant formula (12 mg/L) may be excessively high. Higher concentrations of iron fortification (7 mg/L) have been associated with significantly lower serum copper concentrations

(Hernell & Lonnerdal 2002). Thus, levels of 1.5 mg iron/L, such as those found in regular formulas, may be more appropriate for infants younger than 6 months—given that they provide an amount of absorbed iron similar to the amount absorbed from human milk and that higher iron concentrations do not provide any advantage for improving iron status (Hernell & Lonnerdal 2002).

(iii) Unmodified cow's milk

Cow's milk is a poor source of iron in infancy because of the low iron content (0.2 – 0.3 mg/L) and the relatively low iron bioavailability (Faldella et al. 2003; Lonnerdal et al. 1981). Only about 10% of iron from whole cow's milk is absorbed, explained partly by the high casein content of milk to which the majority of iron is bound (Fomon 1993; Oski 1993). In addition to the relatively low absorption, cow's milk contains high amounts of calcium, which is a strong inhibitor of non-heme iron absorption from other food (Fomon 1993).

The introduction of cow's milk in infancy has been associated with increased blood loss from the gastrointestinal tract in younger infants (Fomon et al. 1981). This response to cow's milk may be associated with age, as younger infants have been shown to have greater amounts of intestinal blood loss in response to cow's milk compared to older infants (Ziegler et al. 1999). This intestinal response to cow's milk gradually disappears between 8 and 12 months (Ziegler et al. 1999). The early introduction of cow's milk in infancy is considered an important risk factor in the development of iron deficiency and iron deficiency anemia (Faldella et al. 2003) and will be discussed in more detail in a section 2.2 (f) (iii).

(iv) Complementary food

Complementary food has been defined as any commercially or home-prepared food offered to an infant when either human milk or infant formula becomes insufficient to satisfy the nutritional requirements of the infant (World Health Organization 1981). Dietary iron requirements for the infant increase during the first year of life because of rapid growth and depleted iron stores around 6 months of age. After this time, adequate consumption of iron–rich complementary food becomes critical to maintain recommended iron intake.

Table 2-4 illustrates the estimated iron needed from complementary food to meet the absorbed iron requirements for breast-fed or iron-fortified formula-fed infants aged 7-12 months. Conservative estimates of iron absorption from breast milk and iron-fortified formula were chosen from data that reflected infants consuming both milk types as well as complementary food. Assuming an intake of 600 ml per day of both milk types, complementary food would have to provide approximately 96% and 58% of the absorbed iron requirements for breast-fed and iron-fortified formula fed infants respectively. Importantly, these values are rough estimates. The amount of iron needed from complementary food for iron-fortified formula fed infants may vary considerably from the value calculated, because of higher energy requirements among formula fed infants (Institute of Medicine 2002) and because the presence of dietary enhancers and inhibitors may effect iron absorption. As well, iron needs from complementary food may differ for infants receiving both breast milk and formula as their primary milk feeding. Nevertheless, these values highlight the importance of complementary food for iron nutrition in the second part of infancy.

In comparison to the variety of food consumed in adulthood, infants consume a more simple diet, often comprised of a few food sources with little or no meat (Lynch & Hurrell 1990). Sources of iron from complementary food are mostly non-heme, with smaller amounts of heme iron consumed from meat (Dallman 1986). In addition, the quantity of complementary food consumed, particularly among infants 6-8 months of age, may be relatively small (Lynch & Stoltzfus 2003). Therefore, the selection of complementary food that is iron dense and contains highly bioavailable iron is key to preventing deficiency. Infant cereal represents the major "targeted" complementary food for iron fortification (Zlotkin 2003). This food is the most commonly consumed complementary food (Fomon 1993; Skinner et al. 1997) and it is recommended as the first food to introduce to infants (Canadian Paediatric Society et al. 1998). Within North

Table 2-4 Estimated iron needed from complementary food to meet absorbed iron requirements for breastfed or iron-fortified formula fed infants aged 7-12 months.							
Milk type	Iron content (mg/L)	Estimated % iron absorbed[a]	Estimated iron absorbed (mg/L)	Amount absorbed per day[d] (mg/day)	Amount absorbed iron required from complementary food[e] (mg/day)	% Absorbed iron requirements needed from complementary food	Required iron intake from complementary food to meet absorbed iron requirements[f] (mg/day)
Human milk	0.35	15[b]	0.05	0.03	0.66	96	6.6
Iron-fortified formula	12	4[c]	0.48	0.29	0.40	58	4.0

[a]Infants consuming complementary food
[b]Abrams et al. 1997.
[c]Fomon et al. 1997.
[d]Assuming average intake of 600 ml/day (Institute of Medicine 2001a)
[e]Calculated using total requirement for absorbed iron (0.69 mg/day) (Institute of Medicine 2001a)
[f]Assumes moderate bioavailability of 10% (Institute of Medicine 2001a)

America, infant cereals are fortified with either 30 mg iron/100g (Canada) or 45 mg iron/100 g (United States) (H.J.Heinz Company of Canada Ltd. 2000; Ziegler & Fomon 1996). In Europe, levels of iron fortification for infant cereals vary more and are generally lower than levels used in North America (Lynch & Hurrell 1990).

The bioavailability of iron in fortified products varies with the level of fortification, the form of fortification iron and its chemical properties that influence iron solubility (Hurrell 2002). The same enhancers and inhibitors that affect iron absorption of non-heme iron naturally found in food, can affect fortification iron (Lynch & Hurrell 1990). Ascorbic acid is added to infant cereals to reverse the inhibitory effects of phytates found in cereals (Hurrell 2002). However, the ascorbic acid in cereals can become oxidized, rendering it ineffective during storage or cooking (Lynch & Stoltzfus 2003).

In North America, changes in the form of fortification iron used in infant cereals have improved bioavailability. Currently in Canada, most infant cereals are fortified with electrolytic iron of a small particle size (Yeung et al. 1986). Electrolytic iron has approximately half the relative bioavailability of ferrous sulfate, which is considered the best form of fortification iron. Unfortunately, ferrous sulfate cannot be used in infant cereals because it causes organoleptic problems in the product (Lynch & Hurrell 1990). An estimate of 4% iron absorption from infant cereals has been reported (Fomon 1987). Therefore, considering current iron fortification levels of 30 mg/100 g cereal, a typical serving of 28 grams will provide 8.4 mg iron—0.34 mg of which will be absorbed. This value represents almost half of the total absorbed iron requirements of infants 7-12 months of age. However, there is some discrepancy in the literature with regards to the amount of iron absorbed from infant cereals and some researchers have suggested an absorption value less than 4% (Fomon 1993). Although infant cereal is a major contributor of iron intake in infancy, its promotion as a sole source of iron to maintain adequate iron status in infants may be disadvantageous, because the amount of cereal offered and the frequency of consumption among infants varies considerably (Walter et al. 1993). Therefore, inclusion of other sources of iron, from both commercial and home-prepared food is important.

In comparison to family (table) food, commercially prepared jarred infant food represents a large proportion of complementary food consumed in industrialized countries, with peak consumption around 9 months of age (British Nutrition Foundation 1995; Kersting et al. 1998; Skinner et al. 1997). It has been estimated in the United States that by the time an infant reaches the age of 12 months, he or she will have consumed an average of 600 jars of infant food (Stallone & Jacobson 1995). Not only is jarred infant food consumed more often, it also costs more in comparison to similar family food and provides little iron (Fomon 1993; Stallone & Jacobson 1995). Strained fruit and juices provide only 0.6 mg of iron /100 g or less and strained vegetables provide only 0.8 mg of iron /100 g or less (H.J.Heinz Company of Canada Ltd. 2000). Strained "mixed" dinners, which contain some meat, provide approximately 0.7 mg of iron/100 g (H.J.Heinz Company of Canada Ltd. 2000). If 10% of this iron were available, only 0.08 mg would be absorbed from a jar (113 g). Strained meat has a higher iron content ranging from 0.9-1.3 mg/100 g and the presence of heme iron increases the amount of iron absorbed from this food (absorption approximately 25%). Unfortunately, this type of jarred infant food is not commonly consumed (Fomon 1993).

The overall diet of older infants in North America has been described as moderately bioavailable (10%), based on evidence of low meat intake and higher reliance on non-heme iron sources (Institute of Medicine 2001a). A recent review by Dewey & Brown (2003) has questioned the iron adequacy of complementary food intake of breast fed older infants from the United States. These researchers reported that the mean iron density (mg iron/100 kcal) of consumed complementary food among infants 6-12 months of age was lower than the average desired iron density (mg/100 kcal), based on the DRI recommendations (Dewey & Brown 2003). However, the sample of infants used in this comparison was relatively small (n=46). There is evidence from studies in developing countries indicating that iron is a "problem nutrient" for complementary food, in that there is a large discrepancy between the iron content in complementary food and the estimated amount required by infants (Dewey & Brown 2003). This discrepancy is caused by the low iron bioavailability of complementary food as well as limited access to heme iron sources in developing countries. However, in North America, there is reasonable access to iron-rich, high bioavailable complementary food such as infant cereal as well as meat, fish and poultry.

Despite suggestions of inadequacy of iron from complementary food, data from efficacy trials have found that infant cereal, infant jarred strained meat and combinations of heme and non-heme iron in home-prepared food are beneficial in maintaining adequate iron status in infants. Walter et al. (1993) monitored the iron status in groups of Chilean infants (approximately 100 infants per group) from 4 to 15 months of age. These infants consumed 25-30 g of rice cereal per day, either fortified with 55 mg iron/100 g or unfortified. Infants received either breast milk or unfortified iron formula and all infants also consumed additional complementary food as per Chilean nutrition guidelines. At 15 months of age, a significantly lower prevalence of IDA was found in breastfed infants who consumed fortified infant cereal (15%) compared to those consuming unfortified cereal (3%). As well, the prevalence of IDA was lower among unfortified formula fed infants consuming fortified cereal (6%) compared to those infants consuming unfortified infant cereal (17%) (Walter et al. 1993). Extrapolation of these results to infants in Canada is somewhat limited, as the level of fortification in the cereal was 25 mg higher per 100 g than the level used in Canada. As well, there are no data from the literature to suggest that daily infant cereal intake in Canada is within the same range as the infants in this study.

The benefits of consuming a daily diet containing 2/3 of a cup of iron fortified cereal (10.2 mg of iron) and two jars of jarred strained meat (0.75-1.5 mg of iron) among infants who received whole cow's milk from 6 to 12 months of age, was studied in Canada (Yeung & Zlotkin 2000). In this study, the control group of infants (n=54) consumed breast milk or formula, no cow's milk and were not provided with fortified infant food. They were compared to the treatment group (n=49) who were provided with the diet described above. At the endpoint, no differences in the incidence of low iron stores (serum ferritin<10 μg/L or hemoglobin<110 g/L) were found between the two groups; suggesting that iron-rich complementary food supplied sufficient iron to compensate for the poor iron content of cow's milk. Engelmann et al. (1998b) found that

26 g of meat/day consumed by partially breast-fed 8 months old infants for 2 months, was sufficient to maintain their hemoglobin status in comparison to a control group consuming 10 g of meat/day. Both groups in this study were allowed to consume milk, cereals, bread and fruits *ad libitum*, but meat purees were provided (Engelmann et al. 1998b). These researchers also investigated the influence of meat on non-heme absorption in two test meals with 8-month-old infants (Engelmann et al. 1998a). One meal contained vegetable puree and the other meal contained vegetable puree with 25 g of added meat. The erythrocyte incorporation of non-heme iron was significantly increased in the test meal with meat (15% absorption) compared to the test meal with out meat (9.9% absorption) (Engelmann et al. 1998a). These results suggest that meat added to infant diets, which contain predominantly non-heme iron, might improve iron absorption. However, current data from North America indicate that meat intake of infants is low (Skinner et al. 1997). Therefore, the effectiveness of adding meat to infants' diets on a larger scale needs to be examined. Reasons for lower meat intake among older infants are unclear. However, a review of current public health guidelines, outlining the order of introduction for complementary food, showed that meat is often recommend after the consumption of infant cereal, vegetables, and fruit—typically around 9 months of age.

(f) Adequacy of iron intake

Studies investigating the iron intake of infants from industrialized countries have been summarized in Tables 2.5, 2.6 and 2.7. Reported iron intake data varied with regards to study design, sample characteristics, dietary components assessed, methodology used and reported descriptive statistics. In general, total iron intakes of infants in these studies were adequate with the exception of infants from low SES (Daly et al. 1998; Greene-Finestone et al. 1991; Nolan et al. 2002) and/or ethnic backgrounds (Daly et al. 1998; Harbottle & Duggan 1994; Williams 2001). Importantly, the adequacy of intakes in each of these studies was based on the iron recommendations for

Table 2-5 Dietary iron intake of infants (Canada)

Author & year / Design	Sample characteristics	n	Age[2] (months)	Iron intake (mg/day)[1]			Method / Diet assessed
				Total	Heme	Non-heme	
(Williams 2001) / Cross-sectional	Receiving IFF Caucasian	32	8-12	7.5 (median)	NR	NR	3-day food record / Non-milk food only
	Chinese			5.5 (median)	NR	NR	
(Goodwin et al. 1999)/ Cross-sectional	Middle SES; attending child care arrangement	36	5-11	10 (median)	NR	NR	24-hr recall (2nd recall with sub-sample) / Food and drink
(Greene-Finestone et al. 1991)/ Cross-sectional	All SES	320	6-18	9.5 ± 0.28	NR	NR	24-hr recall / Food and drink (All milk types)

[1]Mean ± standard deviation unless otherwise indicated.
[2]Data presented for infants (<12 months) only, if analysis permitted.
SES=socioeconomic status; NR=not reported; IFF=iron-fortified formula

Table 2-6 Dietary iron intake of infants (United States)

Author & year/ Design	Sample characteristics	n	Age[3] (months)	Iron intake (mg/day)[1]			Method / Diet assessed
				Total	Heme	Non-heme	
(Devaney et al. 2004b)4) / Cross-sectional	Rnadom sample; middle SES	1162	7-11	15.9 15.9 (median) EPI[2]=7.5%	NR	NR	24-hr recall (2^{nd} recall with sub-sample) / Food, drink and supplements (All milk types)
(Ponza et al. 2004) / Cross-sectional	Random sample;	1159	7-11		NR	NR	24-hr recall (2^{nd} recall with sub-sample) / Food, drink and supplements (All milk types)
	WIC participants			18.5 ± 6.1 EPI[2]=1%			
	Non-WIC participants (income eligible and non-eligible combined)			14.8 ± 6.8 EPI[2]=10%	NR	NR	

[1]Mean ± standard deviation unless otherwise indicated.
[2]Compared to EAR (DRI) values from North America.
[3]Data presented for infants (<12 months), if analysis permitted.
SES=socioeconomic status; EPI=estimated prevalence of inadequacy; NR=not reported; WIC=special supplemental nutrition program for women, infants and children

Table 2-6 Dietary iron intake of infants (United States) continued

Author & year / Design	Sample characteristics	n	Age[3] (months)	Iron intake (mg/day)[1]			Method / Diet assessed
				Total	Heme	Non-heme	
(Nolan et al. 2002) / Prospective	Low SES	147	3	10.9 ± 8.1 EPI[2] = 16.8%	NR	NR	24-hr recall / Food, drink and supplements (Non-BF only)
			6	12.8 ± 7.1 EPI[2] = 8.6%			
			9	12.7 ± 9.6 EPI[2] = 20.1%			
			12	10.5 ± 7.8 EPI[2] = 45.9%			
(Bialostosky et al. 2002) / Cross-sectional	NHANES III; Multiethnic	1620	2-11	16 ± 0.25 (SEM) 14.8 (median)	NR	NR	24-hr recall / Food and drink (Non-BF only)

[1]Mean ± standard deviation unless otherwise indicated.
[2]Compared to EAR (DRI) values from North America.
[3]Data presented for infants (<12 months), if analysis permitted.
SES=socioeconomic status; EPI=estimated prevalence of inadequacy; NR=not reported; WIC=special supplemental nutrition program for women, infants and children

Table 2-6 Dietary iron intake of infants (United States) continued

Author & year / Design	Sample characteristics	n	Age[3] (months)	Iron intake (mg/day)[1] Total	Heme	Non-heme	Method / Diet assessed
(Kannan et al. 1999) / Prospective	Anglo-American	50	6	19 ± 9	NR	NR	24-hr recall / Food and drink (All milk types)
	Asian-Indian American			17 ± 13			
	Anglo-American		12	16 ± 8			
	Asian–Indian American			12 ± 7			
(Skinner et al. 1997) / Prospective; Incomplete block design	Middle-Upper SES	98	2	5 ± 6	NR	NR	24-hr recall / Food and drink (All milk types)
			4	10 ± 32			
			6	15 ± 12			
			8	21 ± 22			
			10	15 ± 12			
			12	13 ± 9			

[1]Mean ± standard deviation unless otherwise indicated.
[2]Compared to EAR (DRI) values from North America.
[3]Data presented for infants (<12 months), if analysis permitted.
SES=socioeconomic status; EPI=estimated prevalence of inadequacy; NR=not reported; WIC=special supplemental nutrition program for women, infants and children

Table 2-7 Dietary iron intake of infants (Europe, New Zealand)

Author & year/ Design	Sample characteristics	n	Age[3] (months)	Iron intake (mg/day)[1]			Method / Diet assessed
				Total	Heme	Non-heme	
(Heath et al. 2002) / Prospective (New Zealand)	Middle SES	140	9	7 (median)	NR	NR	3-day diet records / Food and drink (All milk types)
			12	4.3 (median)	NR	NR	
(Soh et al. 2002) / Cross-sectional (New Zealand)	Random sample from 3 cities; multiethnic; middle SES	42	6-11				3-day weighed diet record / Food, drink and supplements (Non-BF only)
	Male			8.3 (median)	0.08 (median)	7.4 (median)	
	Female			8.6 (median)	0.00 (median)	8.8 (median)	
	Both			EPI[2] = 15%			
(Noble & Emmett 2001) / Cross-sectional (United Kingdom)	Caucasian; Middle-upper SES	1131	8	8.6 8.1 (median)	NR	NR	3-day diet record / Food and drink

[1]Mean ± standard deviation unless otherwise indicated.
[2]Compared to EAR value from United Kingdom.
3Data presented for infants (<12 months) only, if analysis permitted.
SES=socioeconomic status; EPI=estimated prevalence of inadequacy; NR=not reported; BF=breast-fed

Table 2-7 Dietary iron intake of infants (Europe, New Zealand) continued

Author & year/ Design	Sample characteristics	n	Age[3] months)	Iron intake (mg/day)[1]			Method / Diet assessed
				Total	Heme	Non-heme	
(Daly et al. 1998) / Cross-sectional (United Kingdom)	Caucasian and Afro-Caribbean; Low SES (inner-city neighbourhood)	100	7.8	5.2 ± 2.9	NR	NR	3-day weighed food record / Food and drink (Cow's milk fed only)
(Wharf et al. 1997) / Cross-sectional (United Kingdom)	All SES;	137			NR	NR	Diet history / Food and drink
	Males		4	6.1 ± 0.7 (SEM)			
	Females			4.8 ± 0.8 (SEM)			
	Males		8	7.8 ± 1.1 (SEM)			
	Females			7.1 ± 0.8 (SEM)			
	Males		12	6.8 ± 0.6 (SEM)			
	Females			7.1 ± 0.6 (SEM)			

[1]Mean ± standard deviation unless otherwise indicated.
[2]Compared to EAR value from United Kingdom.
3Data presented for infants (<12 months) only, if analysis permitted.
SES=socioeconomic status; EPI=estimated prevalence of inadequacy; NR=not reported; BF=breast-fed

Table 2-7 Dietary iron intake of infants (Europe, New Zealand) continued

Author & year/ Design	Sample characteristics	n	Age[3] (months)	Iron intake (mg/day)[1]			Method / Diet assessed
				Total	Heme	Non-heme	
(Wham 1996) / Cross-sectional (New Zealand)	Middle SES	53	9-24	5.1 ± 3.1	NR	NR	24-hr recall and dietary history questionnaire / Food and drink (All milk types)
(Harbottle & Duggan 1994) / Cross-sectional (United Kingdom)	Indo-Asian	47	4-11	4.6 ± 2.1	NR	NR	5 days weighed diet record / Food and drink (Non-BF only)

[1]Mean ± standard deviation unless otherwise indicated.
[2]Compared to EAR value from United Kingdom.
3Data presented for infants (<12 months) only, if analysis permitted.
SES=socioeconomic status; EPI=estimated prevalence of inadequacy; NR=not reported; BF=breast-fed

the respective countries and these recommendations varied with the study country as well as with the study year (i.e., old versus new nutrient recommendations). As well, iron intakes were possibly influenced by differences in levels of iron fortification of infant food and formulas used in various countries. Low total iron intakes were found in four studies investigating infants from ethnic and/or low socioeconomic (SES) backgrounds (Daly et al. 1998; Harbottle & Duggan 1994; Nolan et al. 2002; Williams 2001).

It is unclear from reviewing these studies whether iron intake may be negatively influenced separately by dietary patterns associated with SES and ethnic backgrounds or whether one of these demographic variables is a confounder of the other. Two studies from the United States indicated that SES background might influence infant iron intake. Nolan et al. (2002) found low iron intakes among infants living in disadvantaged environments and Skinner et al. (1997) found relatively adequate intakes among infants from middle to upper SES backgrounds. Conversely, Williams (2001) found iron intakes from complementary food was significantly lower among Chinese infants compared to Caucasian infants who were from similar SES backgrounds. This finding suggests that cultural feeding practices may, in part, influence infant iron intake and adequacy.

Infants in these studies with high iron intakes typically consumed diets with large amounts of iron-fortified formula or iron-fortified baby food (e.g., infant cereal). Five of the studies suggested that iron-fortified formula intake contributed to the high iron intakes of infants investigated (Devaney et al. 2004b; Heath et al. 2002; Noble & Emmett 2001; Ponza et al. 2004; Soh et al. 2002). In the Feeding Infants and Toddlers Study (FITS), 70% of infants who were breastfed also consumed formula, of which 90% was iron-fortified (Devaney et al. 2004b). As well, only 16% of infants in this sample were receiving any human milk by 12 months (Devaney et al. 2004b). Similarly, Ponza et al. (2004) found that participants in the Special Supplemental Nutrition Program for Women, Infants and Children (WIC) were more likely to consume iron-fortified formula than non-WIC participants. Iron-fortified cereal was suggested to influence infant iron intake in seven of the studies (Devaney et al. 2004b; Greene-Finestone et al. 1991; Heath et al. 2002; Ponza et al. 2004; Skinner et al. 1997; Soh et al. 2002; Wharf et al. 1997).

Infants younger than 11 months frequently consumed infant cereal in the Feeding Infants and Toddlers Study (Devaney et al. 2004b; Fox et al. 2004) and the iron intakes of Canadian infants who consumed infant cereal were found to be significantly higher than infants who did not consume infant cereal (Greene-Finestone et al. 1991).

In addition to the relatively high consumption of iron-fortified infant food products, many of the infants studied were reported to consume little meat (either home prepared or commercial baby food)—regardless of level of iron intake (Devaney et al. 2004b; Heath et al. 2002; Skinner et al. 1997; Soh et al. 2002). Less than 15% of infants younger than 7 months were reported to consume meat and meat intake did not increase appreciably until after 12 months (Fox et al. 2004). Thus, iron-fortified infant food and formula were more likely than meat consumption to influence iron intake. Overall, the infants examined in these studies consumed considerably more commercial infant food (iron-fortified and unfortified) than family food and meat intake was uncommon until late infancy (11 months or older) (Devaney et al. 2004b; Fox et al. 2004; Noble & Emmett 2001; Ponza et al. 2004; Soh et al. 2002).

Several limitations regarding dietary intake data in infants are evident from review of these studies. First, very few studies have investigated iron intake in nationally representative samples in industrialized countries, particularly in Canada. Canadian studies included in this review, represented the most recent data available from the literature and this information was limited to smaller samples sizes that were specific to certain cities. The largest study contained data that was greater than 10 years old (Greene-Finestone et al. 1991). More recent data from nationally representative samples were available from the United States (Devaney et al. 2004a). However, the Feeding Infants and Toddlers Study was limited, because it relied on a commercial list of infants and toddlers rather than a national sampling frame (Devaney et al. 2004a). As well, the WIC participants in the FITS study were under-represented (Ponza et al. 2004). In addition to the need for national data, information about the iron intake of infants from specific "high-risk" groups for sub-optimal iron intake (e.g., low SES, ethnic populations) is lacking. Again, review of the literature shows that this gap is most evident in Canada.

Dietary assessment methodology and the dietary components measured in these studies also had limitations. Ten of the studies used the 24-hr recall to measure intake. This method has been demonstrated in groups of children, to provide mean intakes of most nutrients that are comparable to 7-day diet record (Persson & Carlgren 1984) and to measured food intake (Horst et al. 1988; Iannotti et al. 1994). As well, this method has been considered a sound method for quantitative assessment of nutrient adequacy (Institute of Medicine 2000). Nonetheless, parents may unconsciously over-report their infant's intake in a 24-hr recall in an effort to portray their child as eating well, contrary to under-reporting often observed with 24-hour recalls to assess adult diets (Devaney et al. 2004b). In addition, a parent's ability to estimate the amount actually consumed compared to the amount offered to their infant might influence reported intake values (Devaney et al. 2004b). The total iron intakes presented in these studies were likely influenced heavily by including iron-fortified formula intake in the assessment. Data regarding the iron adequacy of older infants consuming only human milk and complementary food is limited. Furthermore, there is a dearth of studies presenting data on the iron density of complementary food consumed by infants in addition to their primary milk feeding. This information would be beneficial to further understand the role complementary food has in maintaining optimal iron intake.

2.2 Iron deficiency anemia and iron deficiency in infants from industrialized countries

(a) Stages of iron depletion

Iron depletion represents a continuum ranging from mild deficiency with reduced iron stores that cause no physiological impairment to the most severe form where iron stores are depleted and there is marked impairment of physiological function—including evidence of hypochromic, microcytic anemia (Yip 1989). This continuum can be divided into three stages. Marginal depleted iron stores but normal red blood cell morphology characterize the first stage, termed iron depletion (Wharton 1999). This is a mild form of iron deficiency as no evidence of increased iron cellular transport is detected. It also characterizes the iron status of most term infants around 6 months of age, when iron store endowment from birth becomes limited. During this stage, there is a compensatory increase in dietary iron absorption to help prevent further progression of iron depletion (Yip & Dallman 1996). However, marginalized iron balance over time in infants who do not receive adequate iron intake makes them vulnerable to further suboptimal iron status (Yip & Dallman 1996).

In the second stage, termed iron deficiency erythropoiesis or iron deficiency without anemia, red blood cell production becomes limited. Iron delivered to the erythroid precursors and other essential iron compounds is decreased (Yip & Dallman 1996). There is no evidence of a hypochromic or microcytic anemia as iron supply has not been limited enough to produce altered erythrocytes. The final stage, termed iron deficiency anemia, is characterized by the development of microcytic and hypochromic anemia, whereby insufficient iron supply limits hemoglobin synthesis and erythrocyte production is altered (Yip & Dallman 1996).

(b) Laboratory evaluation

There are various hematological and biochemical tests that can be used to assess iron status in infants and these tests reflect different aspects of iron metabolism (Yip & Dallman 1996). No single test is available that is relatively specific for iron status and, therefore, multiple tests are often needed to confirm diagnoses (Fomon 1993; Yip 1989). The choice of iron status test depends largely on the purpose of the assessment (e.g., research versus routine medical practice) as well as the practicality of the testing circumstances (e.g., field setting versus clinical setting) (Yip 1989). As well, irons status assessment in infant populations may be limited by the method of blood collection, as venipuncture methods are more invasive and difficult to obtain from infants than skin puncture methods (Dallman 1993). The venipuncture method is necessary for some of the laboratory tests and the accuracy of this method is generally better than skin puncture methods (Dallman 1993).

(i) Hematological assessment methods

Hematological values are obtained and/or calculated from a complete blood count (CBC) test and include hemoglobin (Hgb) concentration, hematocrit (Hct) (derived from the RBC count and volume), the mean cell volume (MCV) (calculated from Hct divided by RBC count or measured directly using electronic counter), mean cell hemoglobin (MCH) (calculated from Hgb divided by RBC count), mean cell Hgb concentration (MCHC) (calculated from Hgb divided by Hct), and the red cell volume distribution width (RDW) (Boccio et al. 2003). Of these, Hgb concentration and MCV are the most widely used hematological tests in iron status assessment of infants (Dallman 1993).

Hgb concentration reflects the most abundant essential iron compound and is used to assess the severity of anemia (Dallman 1993). However, many other factors can affect Hgb concentration such as other nutrient deficiencies, chronic inflammation, or infection (Boccio et al. 2003). Low Hgb concentration by itself is not specific for anemia due to iron deficiency and is not an indication of early iron deficit (Wu et al. 2002). A value that is less than the 5^{th} percentile of the distribution of Hgb concentration in a healthy reference population is considered indicative of anemia—less than 110 g/L for infants 6 months to 2 years of age (Centers for Disease Control and Prevention 1998). A response of 10 g/L in Hgb concentration to iron therapy is considered a gold standard for a confirmed diagnosis of iron deficiency in addition to anemia. However, this method is difficult to apply in population-based assessments (Wharton 1999). Therefore, low Hgb concentrations, in addition to two or more abnormal values from other hematological (e.g., low MCV) or biochemical tests (e. g., low serum ferritin), are often used to indicate IDA.

The MCV, or average volume of red blood cells, is indicative of microcytic anemia (Centers for Disease Control and Prevention 1998). However, this index is affected by lead poisoning, inflammation or infection as well as thalassemia minor—an inherited form of hemolytic anemia. If these conditions can be excluded, then a low MCV represents a specific indicator of IDA (Fomon 1993). In infants, an MCV<72 femtoliters (fL) is considered abnormal (Fomon 1993).

(ii) Biochemical assessment methods

Under normal conditions, the small amount of ferritin that circulates in the plasma reflects total body ferritin or iron stores (Fomon 1993). A low serum ferritin value is an early indicator of depleted iron stores in the first stage of iron deficiency (Fomon 1993). As well, a low serum ferritin value found in an infant with low Hgb concentration (anemia) is indicative of IDA (Cook 1999). Serum apoferritin is an acute-phase reactant. Therefore, in infants with chronic infection or inflammation, the concentration of serum ferritin will increase and can mask depleted iron stores (Centers for Disease Control and Prevention 1998). In infancy, a serum ferritin value <10 or <12 μg/L has been applied as a cut-off indicating low iron stores (Domellof et al. 2001; Fomon 1993). Although serum ferritin can be an indication of depleted iron stores, iron deficiency is not considered present in an infant until there is evidence of inadequate iron supply for normal physiological function (World Health Organization 2001).

Serum iron, transferrin iron binding capacity (TIBC), and the percent saturation of transferrin with iron (TSAT) are standard measurements indicating the iron supply to erythroid tissue (Wu et al. 2002). Serum iron can be measured directly from a venous blood sample, but is influenced considerably by iron content of meals, inflammation as well as diurnal variation (Centers for Disease Control and Prevention 1998). TIBC measures the iron-binding capacity and reflects the available binding sites on transferrin (Centers for Disease Control and Prevention 1998). The level of TIBC increases with decreasing levels of iron stores and is influenced by inflammation, infection as well as malnutrition (Wu et al. 2002). Both of these indices are used to calculate TSAT (calculated as serum iron divided by TIBC multiplied by 100) (Centers for Disease Control and Prevention 1998). A low TSAT indicates a high proportion of vacant iron-binding sites on transferrin and, thus, iron-depleted erythropoiesis (Centers for Disease Control and Prevention 1998). A TSAT <12% is considered abnormal in infants.

Erythrocyte protoporphyrin (EPP) is an immediate precursor of hemoglobin synthesis, requiring the addition of iron to form heme (Centers for Disease Control and Prevention 1998). Therefore, when iron supply for hemoglobin production is low, the concentration of this molecule increases (Centers for Disease Control and Prevention 1998). This index can be measured directly or derived from solvent extraction of zinc from zinc protoporphyrin (Mei et al. 2003). Under normal conditions iron predominantly joins with protoporphyrin to form heme. However, when iron supply is low, the production of zinc protoporphyrin increases and the ZPP/heme ratio becomes elevated (Wu et al. 2002). Either of these indices reflects iron-deficient erythropoiesis; however, they are both influenced by lead poisoning, inflammation and infection (Centers for Disease Control and Prevention 1998). A cut-off value for EPP>80 μg/dL of erythrocytes has been proposed for infants 12-36 months of age (Fomon 1993). However, this index has not been sufficiently investigated with infants and young children (Aggett et al. 2002).

A more recent test for the early development of iron deficiency is the concentration of serum transferrin receptors (TfR) (Fomon 1993). TfR synthesis of cells (e.g., reticulocytes) is induced with deficient iron supply. Therefore, the concentration of TfR will correlate with tissue requirements for iron (Aggett et al. 2002). TfR is not significantly affected by infection or inflammation (Fomon 1993). However, this index is not widely used in the iron status assessment of infants and children and there are insufficient data regarding normal values (Aggett et al. 2002).

(c) Iron status classification of populations

Two strategies exist for assessing ID and IDA in populations (Yip & Dallman 1996). For ID, the first strategy is to conduct multiple tests, such as those conducted in the National Health and Nutrition Examination Surveys (NHANES) in the United States (Yip 1989). In the most recent of these surveys, NHANES III, serum ferritin, TSAT and EPP tests were used. Two out of three abnormal values were considered indicative of early ID. In addition, Hgb concentration was measured and a low value, in addition to ID, indicated IDA (Looker et al. 1997). The advantages of this strategy are that obtaining multiple abnormal results for an individual, will improve the specificity for diagnosing ID and IDA. However, the practicality and need for abundant resources in performing this number of tests can be prohibitive, particularly in the assessment of large populations or for screening purposes (Yip & Dallman 1996).

A second strategy, often implemented in developing countries, is to use a low Hgb concentration (anemia) as an indicator of ID and IDA (Yip & Dallman 1996). Low Hgb concentration is not specific for IDA. However, ID is the most common cause of anemia and, in industrialized countries, anemia due to other causes such as parasitic infection, current infectious disease, or other nutrient inadequacies is uncommon (Administrative Committee on Coordination 2000). Therefore, anemia identified in individuals from a population with a high prevalence of ID, is most likely IDA (Yip 1989). In the United States, it has been estimated that 45% of individuals with evidence of ID also have anemia. Therefore, for every case of anemia found in a population, there is approximately one case of ID without anemia (Yip 1994). An advantage of this strategy is the relatively low cost and feasibility of obtaining the measurement. This strategy has also been implemented in the United States as part of the screening protocol for eligibility for the WIC program (Food and Nutrition Board 1996).

Recently researchers from the United States have questioned the validity of Hgb concentrations for iron status assessment in their population (Centers for Disease Control and Prevention 1998). Overall, the prevalence and severity of anemia in U.S. children has declined over the past 2 decades (Centers for Disease Control and Prevention 1998). Therefore, the strength of anemia as an indicator of ID has become limited (Centers for Disease Control and Prevention 1998). As well, researchers in Europe have indicated that the current cut-off value for Hgb for infants 6 to 12 months of age (<110 g/L) may be too high and not indicative of abnormal iron status (Aggett et al. 2002; Domellof et al. 2002a; Emond et al. 1996; Sherriff et al. 1999). For example, Emond et al. (1996) reported that the 5th percentile for hemoglobin distribution among 8-month-old British infants was 97 g/L. In Denmark, 20% of 9-month old infants were classified as anemic using the recommended cut-off of <110 g/L, but less than 3% of these infants had indication of ID (serum ferritin <13 μg/L) (Michaelsen et al. 1995). Conversely, some researchers have reported that the cut-off for Hgb concentration may be too low for some infants. Driggers et al. (1981) found 12-month old infants with Hgb concentrations between 110-114 g/L responded to iron therapy with an increase in Hgb concentration and other iron status indicators. The Euro-growth study has produced evidence that the cut-off values for serum ferritin may be inappropriate. Using a cut-off value for serum ferritin of <10 μg/L, 16% of 12-month old infants (n=488) were identified with ID. However, using multiple tests (2 abnormal results from MCV, serum ferritin, TSAT, and TfR) only 7% were classified as ID (Aggett et al. 2002; Male et al. 2001). Thus, more data are needed to establish appropriate cut-off values commonly used in research to assess ID (e.g., serum ferritin) and IDA (Hgb concentration) (Aggett et al. 2002).

(d) Adverse outcomes

In addition to the hematological manifestations of iron deficiency, several non-hematological consequences have been found in infants. Severe iron deficiency has been associated with alterations in brain development, in growth and with immune function and to a lesser extent with stroke and breath-holding spells (Yager & Hartfield 2002). Of these, altered brain development, growth and immune function are more common and will be discussed in further detail.

(i) Alterations in brain development

Iron is unevenly distributed in the human brain, but large amounts are contained in oligodendrocytes that produce myelin (Yager & Hartfield 2002). Iron nutrition has been shown to be important during the weaning period in normal rats, because rapid and maximal brain iron accumulation is occurring (Beard et al. 1993). In humans, the critical period for brain development overlaps the period between 6 and 18 months of age, when infants are at highest risk for iron deficiency (Aggett et al. 2002).

ID is believed to exert an affect on the brain principally through alterations to brain structure (i.e., myelination) and function (i.e., neurotransmitter metabolism) (Pollitt et al. 2002). Direct evidence of this mechanism is derived from neurobiological studies involving the rat model. Brain iron has been shown to be essential for normal myelination in rats, with increased iron uptake from the brain occurring during the peak developmental period of myelin formation (Connor & Menzies 1996; Yu et al. 1986). Iron has also been shown to contribute to neurotransmitter functions in the central nervous system (CNS). Abnormal dopaminergic neurotransmission has been demonstrated in iron-deficient rats (Erikson et al. 2001). Furthermore, studies have shown abnormalities in cognition, motor function and behaviour in rats with IDA, which were not reversible with iron-replete diets (Felt & Lozoff 1996).

Direct evidence of CNS alterations with IDA in human infants has been limited by methodological challenges (Roncagliolo et al. 1998). However, recently neurophysiologic measurements in infants with IDA have been used to assess CNS functional abnormalities. Roncagliolo et al. (1998) measured the auditory brain stem responses in 55 6-month-old infants. Half of these infants had IDA and showed significantly longer central conduction time (using nerve conduction velocity as an indicator of CNS development) than non-anemic infants. As well, the conduction time did not improve once IDA had been corrected and remained poor 6 and 12 months later (Roncagliolo et al. 1998). These researchers suggested these findings supported a role for altered myelination in CNS function due to IDA (Roncagliolo et al. 1998). As well, Sarici et al. (2001) studied the effect of visual-evoked potentials in 20 infants with IDA and found a significant increase in hematological parameters and decrease in visual-evoked potential latencies 12 weeks post-treatment with iron therapy. These researchers concluded that IDA might exert a sub-clinical effect on visual impairment (Sarici et al. 2001).

Most evidence for the effect of IDA on brain development in human infants has come from indirect data that measured behaviour as well as cognitive and psychomotor function using standardized tests. The most common test that has been used is the Bayley Scales of Infant Development (BSID), which consists of three scales: the mental scale (Mental Development Scale or MDI), the motor scale (Psychomotor Developmental Index or PDI), and the infant behavioural record (IBR) (Walter et al. 1989). The majority of evidence from observational studies or from baseline data collected prior to an intervention program, supports a strong association between IDA in infants and delayed development (Idjradinata & Pollitt 1993; Lozoff et al. 1982; Lozoff et al. 1987; Walter et al. 1983; Walter et al. 1989). A relatively consistent finding among these studies is that measurements of MDI are reduced more often than PDI in infants with IDA (British Nutrition Foundation 1995). Data from one of these studies have suggested that ID might also affect development (Walter et al. 1983). A dose-response effect with IDA and developmental outcomes has also been suggested, because infants with more severe anemia were found to have the lowest test scores (Lozoff et al. 1982; Lozoff et al. 1987; Walter et al. 1983; Walter et al. 1989).

More convincing evidence of causality in the relationship between IDA in infants and developmental delay has come from therapeutic and preventive intervention trials. Unfortunately, limited data from these trials provide evidence of causality. In Canada, a double-blinded randomly controlled trial (DBRCT) demonstrated that infants receiving unfortified infant formula from 2 months of age had lower motor development (PDI) scores at 9 and 12 months of age than infants receiving iron-fortified formula (Moffatt et al. 1994). The difference in PDI scores was not seen at 15 months and there was no significant effect seen with mental development (MDI) scores (Moffatt et al. 1994). Although these findings suggest a transient effect of iron status on motor development, the results of this study may have been affected by a considerable loss to follow-up (Moffatt et al. 1994). Another preventive trial used the Griffiths Scale to assess developmental outcome in 24-month-old infants who had received iron-fortified formula from 7 to 18 months of age. The infants in this study came from disadvantaged, inner-city neighbourhood. The results showed a significantly greater decrease in developmental scores in the unfortified formula (cow's milk) group compared to the iron-fortified group (Williams et al. 1999). Importantly, the use of cow's milk was not a "true" control, as other constituents of the formula could not be excluded from producing the beneficial effect (Grantham-McGregor & Ani 2001). Despite the study limitations, the evidence from these data suggest IDA does affect infant development directly, but that this effect may be seen only in disadvantaged environments.

Evidence from therapeutic intervention trials can be divided into data from infants receiving short-term and long-term treatment. Evidence from several short-term (less than 15 days) randomized controlled trials showed no significant benefit from iron therapy (Lozoff et al. 1982; Lozoff et al. 1987; Walter et al. 1989). An additional study found a significant improvement in MDI scores from IDA infants who were treated with iron in comparison to a group of non-IDA iron-replete infants; however, this study lacked a randomized control group (Walter et al. 1983). These data suggest that iron treatment, for shorter duration, has no benefit on the development of infants and young children. However, it may be that the duration of the interventions was not long enough to produce significant changes in development. As well, these studies had relatively small sample sizes, which may have contributed low statistical power (Grantham-McGregor & Ani 2001).

In review of long-term (2-6 months) therapeutic intervention trials, only one relatively small DBRCT showed a significant treatment effect of iron with MDI and PDI test scores (Idjradinata & Pollitt 1993). This study included 141 Indonesian infants 12 to 18 months of age. IDA, ID, and non-IDA/ID infants were randomly assigned to receive iron treatment or placebo for 4 months. Baseline data indicated lower developmental test scores among IDA infants compared to non-IDA infants. Post-intervention results showed that developmental delays (MDI and PDI) were reversed among IDA infants who received iron treatment. Treatment or placebo had no effect on the developmental scores in the other two groups (Idjradinata & Pollitt 1993). An earlier DBRCT from the United Kingdom failed to show a treatment effect with 2 months of iron therapy in infants 17-29 months of age (Aukett et al. 1986). However, this study used the Denver Screening test to measure developmental outcomes; which may not have been sensitive enough for measuring development in infants (Aukett et al. 1986). Three other studies used a non-randomized controlled design with IDA iron-replete infants for controls (Lozoff et al. 1987; Lozoff et al. 1996; Walter et al. 1989). These studies also failed to find a treatment effect of iron therapy among infants who had IDA pre-treatment. Interpretation of these longer-term studies is also limited by the relatively small sample sizes found. As well, three of the studies did not offer placebo to IDA infants due to ethical reasons (Grantham-McGregor & Ani 2001). Thus, only one DBRCT from Indonesia has suggested that developmental delay is reversible and caution should be applied in extrapolating these results to other populations.

In addition to the data from these trials, there is some evidence from the literature that IDA is associated with adverse longer-term developmental outcome. Lozoff et al. (2000) has demonstrated that children who had IDA during infancy produced lower test scores for mental and motor development 5 and 10 years later compared to those infants who were iron-sufficient as infants, irrespective of whether the infants had received treatment for the IDA. Although attempts were made to statistically control for potential confounders related to home and family environment, other unmeasured variables may have affected the children who had earlier IDA differently than those children who had been iron-sufficient in infancy (Lozoff et al. 2000).

Several overall limitations to these above studies must be noted. First, these studies have assumed that the developmental measurement tools used accurately measured the effects of IDA on cognition in young children. However, researchers have questioned the sensitivity of these psychometric tools (Pollitt 2001). In particular, the validity and sensitivity of the BSID when used in infants and young children under 18 months has been challenged (Pollitt 2001). As well, the power of these scales to predict later performance on intelligence tests in preschool and school years has been disputed (Pollitt 2001). A second limitation of the studies reviewed relates to the establishment of iron status. The criteria to define IDA and ID varied among studies, making comparisons difficult (British Nutrition Foundation 1995). Finally, the effect of confounding environmental variables cannot be ignored (Figure 2-4). The findings by Lozoff et al. (2000) cannot exclude the role of environmental factors contributing to the long-term developmental outcomes observed in infants with IDA. Variables such as maternal depression, lower maternal education and lack of stimulation in the home may also exert an influence on infant development, either alone or in relation to IDA (Pollitt 2001). Evidence of functional isolation factors has been demonstrated among infants with IDA (Lozoff et al. 1998). These infants were more wary, hesitant and easily tired in

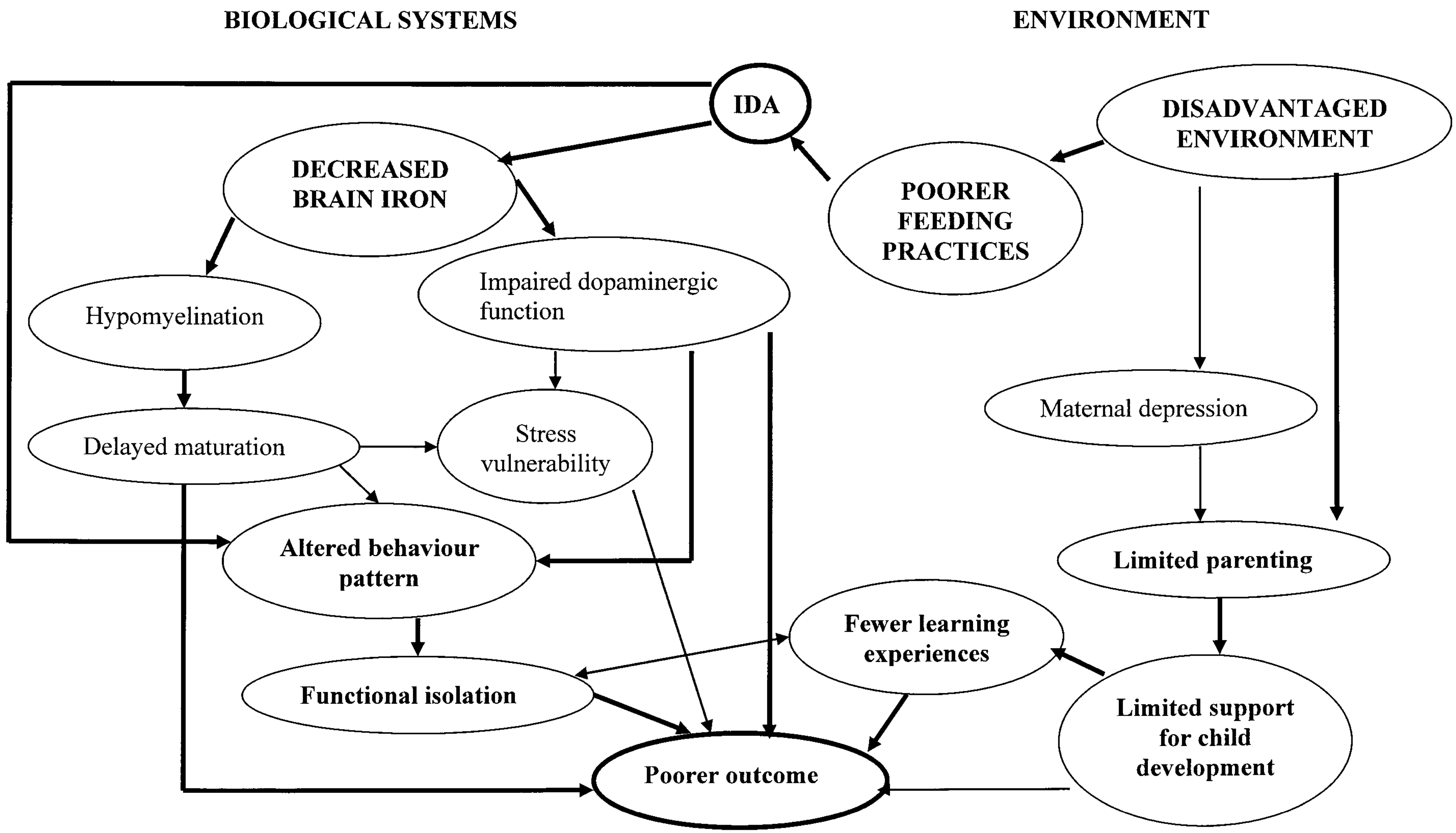

Figure 2-4 Conceptual model for developmental effects of IDA in infancy
From Lozoff et al. 1998.

comparison to a group of infants with better iron status. As well, the infants with IDA maintained closer contact with their caregivers and were less likely to interact with their environment (Lozoff et al. 1998). In summary, it is unclear from the literature how much of the association between IDA in infancy and poor developmental outcome is due to environmental factors. Although there is a lack of definitive evidence demonstrating a causal role for iron, the available data suggest that poor iron status in infancy is a risk indicator of sub-optimal development (Lozoff et al. 1998).

(ii) Alterations in growth and immune function

Several studies have reported a relationship between iron status and growth in infants and young children (Allen 1994; Michaelsen 1997; Persson et al. 1998). Available evidence from iron supplementation trials has indicated that iron treatment significantly improved the growth of infant and young children who had severe anemia, secondary to iron deficiency (Rivera et al. 2003). No effect of iron treatment on growth was found in infants without IDA (Rivera et al. 2003). The mechanisms by which IDA effects growth is not clear, but it may result from reduced oxidation reactions that occur with functional deficiency, from decreased appetite, or from increased morbidity secondary to lower immune function (Rivera et al. 2003).

There is conflicting evidence of the relationship between IDA and infection as well as immune function—with data supporting that IDA may both impair or improve immune function and susceptibility to infection (Walter et al. 1997). Most evidence supporting a positive association between iron supplementation and infection rates has been derived from studies with subjects living in poorer, unsanitary living conditions. Other studies examining the relationship between infection and IDA were hampered by cross-sectional or retrospective study design, so that it was unclear if IDA was a cause or outcome of the infection. Importantly, iron fortification of food was not shown to significantly alter the morbidity of infants in two large-scale IDA prevention trials (Moffatt et al. 1994; Walter et al. 1989).

An unfavourable effect of iron deficiency on human T-cell and phagocyte function has been observed *in vitro*. As well, alterations in the production of cytokines, such as Interleukin-2 have been demonstrated in children (Galan et al. 1992). Further research is required to improve current understanding of the relationship between iron and immune function.

(e) Estimated prevalence

ID is the most common nutrient deficiency affecting more than 2 billion people worldwide (Ramakrishnan 2002). In industrialized nations, ID has been found in approximately 17% of children 0 to 4 years of age (Ramakrishnan 2002). In particular, it appears that particular subgroups of the pediatric population in industrialized countries may be vulnerable to iron deficiency. Table 2-8 summarizes reported prevalence rates for infants in industrialized countries for the past 20 years.

Several limitations of these studies must be considered. As discussed previously in section 2.2 (c), discrepancies exist in the literature regarding appropriate cut-off values to use for iron status assessment of infants from various population groups. Researchers have used a wide variety of cut-off criteria. Thus, prevalence rates may overestimate or perhaps in some populations, underestimate the magnitude of this health problem (Aggett et al. 2002). Comparisons among these studies are also limited because of the variations in sample size, use of iron status indicators, and sample characteristics. In North America, the level of iron fortification of both formula and iron-fortified cereal is greater and the types of iron fortification differ in some infant cereals, which may explain part of the variation among prevalence rates.

There have been very few studies conducted regarding ID and IDA prevalence in infants and young children in Canada. Most of the data are limited to particular subgroups and strongly suggest that particular ethnic groups (i.e., Chinese, Aboriginal) and infants from disadvantaged environments have higher prevalence rates. There are no national data to provide evidence of this health problem in the general pediatric population. A larger study from the early 1990s, conducted with a more representative

Table 2-8 Prevalence of iron deficiency anemia (IDA) and iron deficiency (ID) among infants in industrialized countries

Country & Study	Sample Characteristics	n	Age (months)	Prevalence (%)		Diagnostic Criteria	
				IDA	ID	IDA	ID
Canada (Williams 2001)	Multiethnic (Caucasian, Chinese)	94	8-12	12	15	Hgb<110 g/L + SF≤12 μg/L	Hgb≥110 g/L + SF≤12 μg/L
			13-17	3	40		
Canada (Willows et al. 2000a)	Inuit	172	2	1.3	3.8	Hgb<90g/L + MCV<77 fL (2 months); Hgb<95 g/L+ MCV<74 g/L (3-6 months); Hgb<105 g/L + MCV<70 fL (0.5-2 years)	SF<12 μg/L
			6	24.4	46.5		
			12	26.3	60		
Canada (Willows et al. 2000b)	First Nations	386	9	11	NR	Hgb<110 g/L + MCV<71 fL	NR

Hgb=hemoglobin; SF=serum ferritin; SI=serum iron; IDA=iron deficiency anemia; IDE=iron deficient erythropoiesis; ID=iron deficiency; TIBC=total iron binding capacity; TSAT=transferrin saturation; transferrin TfR=transferrin receptor concentration; ZZP=zinc protoporphyrin; ZEP=zinc erythrocyte protoporphyrin; FEP=free erythrocyte protoporpyhyrin; RBC=red blood cells; MCV=mean corpuscular volume; SES=socioeconomic status; NR=not reported

Table 2-8 Prevalence of iron deficiency anemia (IDA) and iron deficiency (ID) among infants in industrialized countries (continued)

Country & Study	Sample Characteristics	n	Age (months)	Prevalence (%)		Diagnostic Criteria	
				IDA	ID	IDA	ID
Canada (Hodgins et al. 1998)	Inuit	172	4-9	24	15	Hgb<105 g/L + SF<10 μg/L or MCV<70 fL	SF<10 μg/L or MCV<70 fL
Canada (Sawchuk et al. 1998)	First Nations	25	6-24	52	NR	Hgb<100 g/ L or Hgb<110 g/L + SF<10 μg/L or MCV<70 fL	NR
Canada (Innis et al. 1997)	Multiethnic background	434	9	6.9	24.2	Hgb≤101 g/L or Hgb≤110 g/L + 2 or 3 abnormal indicators of iron status from SF≤10 μg/L, TIBC>60 μmmol/L, ZEP>70 μmmol/mol heme	SF≤10 μg/L without IDA

Hgb=hemoglobin; SF=serum ferritin; SI=serum iron; IDA=iron deficiency anemia; IDE=iron deficient erythropoiesis; ID=iron deficiency; TIBC=total iron binding capacity; TSAT=transferrin saturation; transferrin TfR=transferrin receptor concentration; ZZP=zinc protoporphyrin; ZEP=zinc erythrocyte protoporphyrin; FEP=free erythrocyte protoporpyhyrin; RBC=red blood cells; MCV=mean corpuscular volume; SES=socioeconomic status; NR=not reported

Table 2-8 Prevalence of iron deficiency anemia (IDA) and iron deficiency (ID) among infants in industrialized countries (continued)

Country & Study	Sample Characteristics	n	Age (months)	Prevalence (%)		Diagnostic Criteria	
				IDA	ID	IDA	ID
Canada (Zlotkin et al. 1996)	4 Canadian cities Middle SES	428	8-15	4.3	33.9	Hgb≤110 g/L + either SF≤10 μg/L or FEP≥100 μg/L	SF≤10 μg/L
Canada (Lehmann et al. 1992)	Low SES	218	10-14	25	37	SF≤10 μg/L with either Hgb≤115 g/L or MCV≤72 fL	SF≤10 μg/L
Canada (Greene-Finestone et al. 1991)	All SES Low SES Upper SES	320	6-18	3.5 8.2 1.6	10.6 NR NR	Hgb<110 g/L	Hgb≥110 g/L + SF<10 μg/L
Canada (Chan-Yip & Gray-Donald 1987)	Chinese	346	6-36	NR	12.1	NR	1 abnormal iron index (low SF, elevated FEP, elevated TIBC) + ↑ Hgb by 10 g/L in response to iron therapy

Hgb=hemoglobin; SF=serum ferritin; SI=serum iron; IDA=iron deficiency anemia; IDE=iron deficient erythropoiesis; ID=iron deficiency; TIBC=total iron binding capacity; TSAT=transferrin saturation; transferrin TfR=transferrin receptor concentration; ZZP=zinc protoporphyrin; ZEP=zinc erythrocyte protoporphyrin; FEP=free erythrocyte protoporpyhyrin; RBC=red blood cells; MCV=mean corpuscular volume; SES=socioeconomic status; NR=not reported

Table 2-8 Prevalence of iron deficiency anemia (IDA) and iron deficiency (ID) among infants in industrialized countries (continued)

Country & Study	Sample Characteristics	n	Age (months)	Prevalence (%)		Diagnostic Criteria	
				IDA	ID	IDA	ID
United States (Gupta et al. 1999)	Multiethnic infants of young mothers, WIC participants	175	6-59	34.9	NR	Hgb<112 g/L	NR
United States (Looker et al. 1997)	Multiethnic (NHANES III)	1339	12-24	3	9	Hgb<110 g/L + 2 of TSAT<10%, SF<10 µg/L, or FEP>1.42 µmol/L RBC	2 of TSAT<10%, SF<10 µg/L, or FEP>1.42 µml/L RBC
United States (Eden & Mir 1997)	Multiethnic (4 urban pediatric clinics)		12-36	10	7	Hgb<110 g/L + SF<10 µg/L + FEP>0.62 µmol/L	Hgb>110 g/L + SF<10 µg/L + FEP>0.62 µmol/L
Iceland (Thorsdottir et al. 2003)	High birth weight, breastfed	114	12	2.7	20	Hgb<105 g/L, SF<12 µg/L + MCV<74 fL	SF<12 µg/L + MCV<74 fL

Hgb=hemoglobin; SF=serum ferritin; SI=serum iron; IDA=iron deficiency anemia; IDE=iron deficient erythropoiesis; ID=iron deficiency; TIBC=total iron binding capacity; TSAT=transferrin saturation; transferrin TfR=transferrin receptor concentration; ZZP=zinc protoporphyrin; ZEP=zinc erythrocyte protoporphyrin; FEP=free erythrocyte protoporpyhyrin; RBC=red blood cells; MCV=mean corpuscular volume; SES=socioeconomic status; NR=not reported

Table 2-8 Prevalence of iron deficiency anemia (IDA) and iron deficiency (ID) among infants in industrialized countries (continued)

Country & Study	Sample Characteristics	n	Age (months)	Prevalence (%) IDA	Prevalence (%) ID	Diagnostic Criteria IDA	Diagnostic Criteria ID
New Zealand (Heath et al. 2002)	Caucasian	74	9	7	19 (IDE)	Hgb<110 g/L + MCV<77 fL	(IDE) MCV<77 fL + ZPP<800 µg/L RBC
			12	7	22 (IDE)		
			18	7	NR (IDE)		
			24	0	13 (IDE)		
Europe (Male et al. 2001)	Euro-growth study (11European areas)	488	12	2.3	7.2	Hgb<110 g/L + 2 of MCV<70 fL, SF<10 µg/L, TSAT<10%, TfR>4.4 mg/L	Two of MCV<70 fL, SF<10 µg/L,TSAT<10 %, Tfr>4.4 mg/L
United Kingdom (Sherriff et al. 1999)	Caucasian; Middle-High SES	1767	12	<1	5	Hgb<100 g/L + SF<16 µg/L (12 months); Hgb<100 g/L + SF<12 µg/L (18 months)	SF<16 µg/L (12 months); SF<12 µg/L (18 months)
			18	<1	5		

Hgb=hemoglobin; SF=serum ferritin; SI=serum iron; IDA=iron deficiency anemia; IDE=iron deficient erythropoiesis; ID=iron deficiency; TIBC=total iron binding capacity; TSAT=transferrin saturation; transferrin TfR=transferrin receptor concentration; ZZP=zinc protoporphyrin; ZEP=zinc erythrocyte protoporphyrin; FEP=free erythrocyte protoporpyhyrin; RBC=red blood cells; MCV=mean corpuscular volume; SES=socioeconomic status; NR=not reported

Table 2-8 Prevalence of iron deficiency anemia (IDA) and iron deficiency (ID) among infants in industrialized countries (continued)

Country & Study	Sample Characteristics	n	Age (months)	Prevalence (%) IDA	Prevalence (%) ID	Diagnostic Criteria IDA	Diagnostic Criteria ID
Sweden (Persson et al. 1998)	Urban-dwelling; SES NR	76	12	0	26	MCV<73 fL, SF<10 μg/L + serum iron<10 μmol/L	SF<12 μg/L
Australia (Oti-boateng et al. 1998)	Caucasian	88	6-12	3	20	Hgb<110 g/L + SF<15 μg/L and/or TF>3 g/L, TSAT>12% + SI<8 μmol/L	Hgb>110 g/L + SF<15 μg/L and/or TF>3 g/L, TSAT>12% + SI<8 μmol/L
	Asian			11	5		
Norway (Wandel et al. 1996)	Norwegian	70	12	0	15	Hgb<110 g/L + SF<15 μg/L	SF<15 μg/L
	Immigrant			11	32		

Hgb=hemoglobin; SF=serum ferritin; SI=serum iron; IDA-=ron deficiency anemia; IDE=iron deficient erythropoiesis; ID=iron deficiency; TIBC=total iron binding capacity; TSAT=transferrin saturation; transferrin TfR=transferrin receptor concentration; ZZP=zinc protoporphyrin; ZEP=zinc erythrocyte protoporphyrin; FEP=free erythrocyte protoporpyhyrin; RBC=red blood cells; MCV=mean corpuscular volume; SES=socioeconomic status; NR=not reported

Table 2-8 Prevalence of iron deficiency anemia (IDA) and iron deficiency (ID) among infants in industrialized countries (continued)

Country & Study	Sample Characteristics	n	Age (months)	Prevalence (%) IDA	Prevalence (%) ID	Diagnostic Criteria IDA	Diagnostic Criteria ID
New Zealand (Wham 1996)	Multi-ethnic (Caucasian, Maori and pacific islander)	53	9-24	18.9 (anemia)	13.2	(anemia) Hgb<110 g/L	SF<10 µg/L
Denmark (Michaelsen et al. 1995)	Random sample	91	2	0	0	Hgb<105 g/L, SF<13 µg/L + TSAT<10%	SF<13 µg/L + TSAT<10%
			6	0	0		
			9	0	0		
Italy (Pisacane et al. 1995)	Breast fed only (no iron supplementation or fortification)	30	12	20	43	Hgb<110 g/L + SF<10 µg/L	SF<10 µg/L
United States (Sadowitz & Oski 1983)		280	9-12			Hgb<110 g/L + SF<12 µg/L + FEP<300 µg/L + MCV<70 fL	Hgb>110 g/L + SF<12 µg/L + FEP<300 µg/L + MCV<70 fL
	Caucasian			2.7	19.6		
	African American			14.3	19.7		

Hgb=hemoglobin; SF=serum ferritin; SI=serum iron; IDA=iron deficiency anemia; IDE=iron deficient erythropoiesis; ID=iron deficiency; TIBC=total iron binding capacity; TSAT=transferrin saturation; transferrin TfR=transferrin receptor concentration; ZZP=zinc protoporphyrin; ZEP=zinc erythrocyte protoporphyrin; FEP=free erythrocyte protoporpyhyrin; RBC=red blood cells; MCV=mean corpuscular volume; SES=socioeconomic status; NR=not reported

sample, has indicated that the prevalence rate of IDA is relatively low, but that deficient iron stores may be a concern (Greene-Finestone et al. 1991).

In the United States, there has been an overall decline in IDA prevalence in infants over the past few decades (Looker et al. 1997; Yip et al. 1987a; Yip et al. 1987b). Among infants from middle-income backgrounds, anemia rates have decreased from 6.2% in the early 1970s to approximately 2.8% in the early 1980s—with no strong evidence of iron deficiency (Yip et al. 1987b). As well, a decline in anemia prevalence rates (Hgb<103 g/L) among infants from low-income backgrounds has been shown in six states, decreasing from 7.8% in 1975 to 2.9% in 1985 (Yip et al. 1987a). Sherry et al. (2001) have reported that the decline in anemia prevalence among infants from disadvantaged environments has continued into the 1990s and found that in five states, the rate was 5%. These researchers have attributed the decline to the benefits of public health programs and to overall improvements in infant feeding practices (Sherry et al. 2001; Yip et al. 1987a; Yip et al. 1987b). However, Gupta et al. (1999) reported that these data might not reflect the prevalence for all infants living in poverty in the United States, as they found 35% of infants born to adolescent mothers were anemic, despite receiving WIC services and a reported history of iron-fortified formula use. National data form the NHANES III showed that 3% of infants were found to have IDA and 9% of infants were iron deficient, representing 700,000 infants with evidence of ID and 240,000 infants with IDA (Looker et al. 1997).

Within European countries, low prevalence rates have been found in larger representative samples (Male et al. 2001; Sherriff et al. 1999). However, the pattern of higher prevalence rates among low income and ethnic pediatric subgroups is evident (Booth & Aukett 1997; Wandel et al. 1996), including data from Australia and New Zealand (Oti-boateng et al. 1998; Wham 1996). In summary, there is evidence that IDA prevalence rates among the general infant population in industrialized countries have declined during the past few decades. However, the prevalence of ID remains a concern. Importantly, infants from certain ethnic backgrounds and disadvantaged environments appear at to be at higher risk of IDA and ID.

(f) Associated risk factors

Modifiable dietary risk factors have been shown to be important predictors of risk for infant IDA, including primary milk type feeding (Greene-Finestone et al. 1991; Male et al. 2001; Mira et al. 1996; Pisacane et al. 1995; Pizarro et al. 1991; Williams 2001; Willows et al. 2000b) and characteristics of complementary food intake (Greene-Finestone et al. 1991; Innis et al. 1997; Kattelmann et al. 2001; Lehmann et al. 1992; Mira et al. 1996; Requejo et al. 1999; Wharf et al. 1997; Williams 2001). In addition, maternal iron status, birth weight, growth velocity, gender, ethnicity, *Helicobacter pylori* infection, and SES factors have been associated with infant IDA and are important indicators in identifying vulnerable infants (Allen 2000; Barabino 2002; Greene-Finestone et al. 1991; Lehmann et al. 1992; Male et al. 2001; Parkinson et al. 2000; Savoie & Rioux 2002; Sherriff et al. 1999). The following discussion provides details of the evidence for these risk factors.

(i) Maternal iron status, birth weight, growth velocity and gender

Current data are limited regarding the association between maternal and infant iron status. As reviewed by Allen (2000), no significant association between prenatal maternal Hgb concentration and cord blood Hgb concentration has been shown. However, a significant association of maternal Hgb and serum ferritin concentration with cord blood ferritin has been demonstrated (Allen 2000). The majority of studies have investigated the effects of maternal anemia on infants at or shortly after birth. Two studies investigating longer term effects in infants found that maternal anemia (Hgb<110 g/L and serum ferritin<12 μg/L) was associated with infant iron status at 9 months (Savoie & Rioux 2002) and 12 months of age (Colomer et al. 1990), when controlling for feeding practices, morbidity and SES. Overall, the data suggest that moderate-severe maternal IDA (85-100 g/L) is associated with aberrant infant iron status (Rao & Georgieff 2002). Despite adequate maternal iron status, fetal iron deficiency can occur under certain conditions, including gestational diabetes mellitus (GDM) and severe hypertension (Rao & Georgieff 2002). GDM can lead to sub-optimal TfR function and severe hypertension can cause intrauterine growth retardation (Rao & Georgieff 2002).

Several studies have found evidence of an association between birth weight and iron status, including more recent data that indicated infants with higher birth weight had higher iron stores at 12 months (Male et al. 2001). These data were similar to Sherriff et al. (1999) who found a 1 kilogram increase in birth weight was associated with 22% increase in iron stores at 12 months, when controlling for growth velocity. These findings are not surprising given that total body iron at birth varies with birth weight (Fomon 1993). Low birth weight, <2500 grams, is a strong marker for IDA risk throughout the first year of life.

Infants who grow more rapidly have been shown to have poor iron stores in late infancy, independent of their birth weight (Male et al. 2001; Sherriff et al. 1999; Thorsdottir et al. 2003). Weight gain from birth to 12 months was correlated with TfR concentrations at 12 months (Male et al. 2001), indicating a higher tissue requirement for iron to support the rapid growth. Sherriff et al. (1999) reported that a higher growth velocity between 8 and 12 months was associated with higher depleted iron stores at 12 months. As well, a higher weight gain at 12 months was associated with poor iron stores at 18 months (Sherriff et al. 1999).

More recent studies have found an association between gender and prevalence of ID and IDA in infants, irrespective of differences in growth between males and females. Thorsdottir et al. (2003), found a significant difference in the prevalence of iron deficiency between male and female infants at 12 months of age, 27% versus 12% respectively. At both 12 and 18 months of age, males were found to have lower Hgb concentration than females (Sherriff et al. 1999). Gender differences were also found in MCV and ZPP measurements in 9-month-old breastfed infants, when controlling for possible explanatory variables such as birth weight, postnatal weight gain and complementary food energy intake. In addition, iron supplementation from 6 to 9 months had no affect on these gender differences. These researchers suggested that gender differences might reflect genetic or hormone-related differences in iron metabolism (Domellof et al. 2002c).

(ii) Ethnicity, socioeconomic status (SES) and *Helicobacter pylori* (*H. pylori*)

Both ethnic (i.e., Asian, Aboriginal, immigrant) and SES (i.e., low income and education) background have been associated with higher prevalence of IDA in infants from industrialized countries (refer to Table 2-8). Within Canada, Greene-Finestone et al. (1991) found that infants from disadvantaged backgrounds had a significantly higher prevalence rate of IDA than infants from middle-high income families, 8.2% versus 1.6% respectively. Furthermore, these researchers found that SES was significantly associated with nutrition knowledge, as fewer mothers from low SES were able to identify iron-rich infants food sources than mothers from middle-high SES backgrounds (Greene-Finestone et al. 1991). Similarly, data from the Euro-growth study have suggested as strong association between maternal education and IDA prevalence (Male et al. 2001).

There is evidence of higher IDA prevalence rates among infants from a variety of ethnic backgrounds. However, rather than a true "ethnic-related" risk for IDA, it is more likely that ethnicity is strongly associated with SES background. Many immigrant and indigenous populations in industrialized countries live within disadvantaged environments, including inadequate housing, food and access to health care (Booth & Aukett 1997; First Nations and Inuit Regional Health Survey National Steering Committee 1999). An inability to adequately provide optimal iron nutrition may be associated with this environment. In addition, cultural infant feeding practices related to ethnic background are important. Differences in assimilation to predominant infant feeding practices (e.g., iron-fortified infant products) among immigrants and indigenous groups may explain differences in the prevalence rates with various ethnic infant populations (Marx 1997).

Helicobacter pylori (*H. pylori*) are a bacteria causing gastrointestinal infection and have been found to be strongly associated with low SES (e.g., overcrowded housing) in children (Sinha et al. 2002). This infection has been associated with refractory IDA, unresponsive to iron therapy, particularly in adolescents and adults (Barabino 2002; Sinha et al. 2002). However, this association has not been well studied in young infants and children. Parkinson et al. (2000) investigated the association between *H. pylori* and iron status in the Alaskan Native population. These researchers found a 1.15 relative risk of low iron stores for individuals, 20 years and younger, who were seropositive for *H. pylori* (Parkinson et al. 2000). More than 25% of the individuals who were iron deficient did not have evidence of *H. pylori* infection; thus, low iron intake may have also contributed to low iron stores in this population (Parkinson et al. 2000).

(iii) Primary milk type feeding

There is overwhelming evidence that the early introduction of cow's milk and the quantity of cow's milk consumption are both independent risk factors for ID and IDA development in infancy (Booth & Aukett 1997; Male et al. 2001; Michaelsen et al. 1995; Mira et al. 1996; Sadowitz & Oski 1983; Williams 2001; Willows et al. 2000b). Numerous studies have found a consistently strong association between early introduction of this primary milk type feeding and IDA by 9-12 months of age. For every month of cow's milk feeding, the risk of ID increased by 18% and the risk of IDA increased by 39% in 12-month-old infants studied in Europe (Male et al. 2001). As well, introduction of cow's milk as late as 9 months (Williams 2001) and 12 months of age (Male et al. 2001) was shown to predict an increased risk of IDA in later infancy.

Data are less clear regarding the associated risk of duration of breastfeeding and poor iron stores. Some researchers have found that longer duration of breastfeeding is associated with better iron stores in late infancy. Greene-Finestone et al. (1991) reported the prevalence rates for infants who were breastfed for more than 6 months was 10.7%, for less than 6 months was 14.4%, and never breastfed was 18.7%. As well, longer duration of breastfeeding among Icelandic infants was associated with adequate iron status at 12 months (Thorsdottir et al. 2003). Conversely, Pisacane et al. (1995) reported that exclusive breastfeeding for at least 7 months was associated with lower iron stores at 12 months of age, but not associated with anemia. Similarly, Siimes et al. (1984) reported that exclusively breastfed infants had significantly lower serum ferritin and MCV indicators at 9 months of age than infants who had received iron-fortified formula from 3 to 9 months of age. In Canada, Innis et al. (1997) reported a higher prevalence of IDA among infants who received breast milk for 9 months (15%) compared to infants who had received breast milk for less than 8 months (6%). Similar to previous studies, the breastfed infants in this study also had significantly lower serum ferritin (low iron stores) at 9 months than those infants who had not received breast milk, irrespective of duration (Innis et al. 1997). Thus, it appears that the risk of breastfeeding may be associated with lower iron stores in late infancy, but the association is not evident with more severe iron depletion.

Observational and clinical studies have shown a consistent association between iron-fortified formula and iron status indicators, with a decreased risk of ID associated with iron-fortified formula (Daly et al. 1996; Male et al. 2001; Moffatt et al. 1994; Pizarro et al. 1991). As well, Williams (2001) found that an absence of iron-fortified formula use was a significant predictor or poor iron status among infants 8-36 months of age.

In summary, the prevalence of low iron stores appears to be higher among breastfed infants in comparison to iron-fortified formula fed infants. However, IDA risk with breastfeeding does not appear to be as great as the risk associated with the quantity and early introduction of unmodified cow's milk. Importantly, the confounding effects of iron content and intake of complementary food may have limited many of these studies. As well, there are no data to indicate the specific risk for infants who consume more than one type of primary milk type feeding. Although, the evidence suggests that infants fed iron-fortified formula may have a low risk of developing ID and IDA, their risk increases greatly in late infancy when transitioning to unmodified cow's milk. If these infants do not have an adequate iron intake from other dietary sources, their iron status will be compromised—particularly during the second year of life.

(iv) Complementary food intake

Around 6 months of age the selection of appropriate, iron-rich complementary food is important for maintaining optimal iron balance in late infancy (Dallman 1986). Various factors contribute to inadequate iron intake in infancy in addition to primary milk feeding and complementary food choice (Figure 2-5). These include, but are not limited to characteristics of the mother, the infant and their environment. An appreciation of these factors is necessary to better understand the relationship among risk factors that contribute to poor iron intake in infancy and increase susceptibility to IDA. As well, this information is important to identify potential areas for prevention strategies aimed at improving iron intake and status.

The risk of IDA is negatively associated with intake of iron-fortified infant cereal in industrialized countries (Greene-Finestone et al. 1991; Marx 1997; Yip et al. 1987a; Yip et al. 1987b). The consumption of iron-fortified cereal for less than 6 months duration was associated with a 3.15 times risk of IDA among infants 10-14 months of age, living in disadvantaged environments (Lehmann et al. 1992). Greene-Finestone et al. (1991) found an IDA prevalence rate of 5.7% for infants who consumed infant cereal for 3 months duration, 2.7% among infants who consumed infant cereal for 6 months, and no IDA among infants who consumed infant cereal for 12 months.

Early (3-4 months) or late (6 months) introduction of complementary food does not appear to be associated with differences in iron status in late infancy (Innis et al. 1997; Kattelmann et al. 2001). However, Requejo et al. (1999) reported that children 2-6 years of age who consumed meat earlier than 8 months of age had better iron status than those children who had been introduced to meat at a later time.

The composition of complementary food has been associated with iron status of infants. Complementary food with known inhibitors, such as phytates in bread, was shown to be negatively associated with iron stores at 9 months of age (Michaelsen et al. 1995). Heme iron, found in meat products, is a highly bioavailable form of iron. Thus, an association between low meat intake in late infancy and iron status is plausible. Williams (2001) reported that the median meat, fish and poultry consumption among infants 8-36 months was lower among infants with low iron status versus sufficient iron status. This researcher also found that infants fed less than 30 g of meat/day had a 3.77 times greater risk of IDA than infants fed greater than or equal to this amount

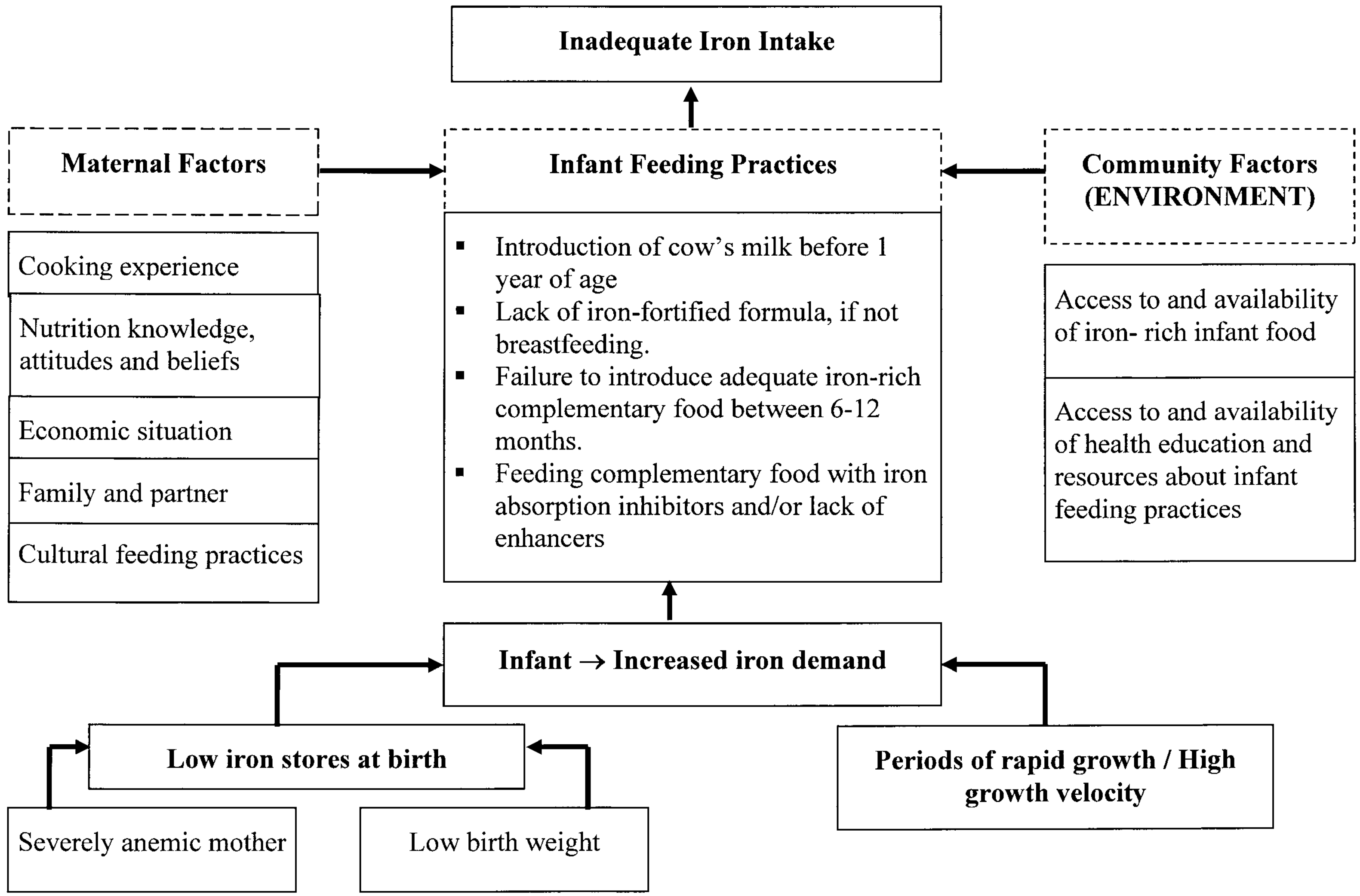

Figure 2-5 Contributing factors for inadequate iron intake in infants from industrialized countries–Adapted from World Health Organization 2001.

(Williams 2001). Similarly, in a case-control study, Mira et al. (1996) found that the average daily intake of heme iron was significantly lower among iron-depleted infants aged 12-36 months (0.26 mg versus 0.42 mg). These researchers calculated that a low intake of heme iron (less than 0.71 mg/day) was significantly associated with and odds ratio of 3.0 (Mira et al. 1996).

2.3 IDA prevention strategies in infancy

Primary and secondary prevention are two important population-based approaches for addressing the issue of infant IDA. Worldwide, primary prevention strategies such as iron supplementation, iron fortification and food-based approaches have been developed and implemented in an effort to prevent the incidence and prevalence of IDA. No one approach is suitable for all populations and in all settings. However, a combination of strategies is thought to improve success (Howson et al. 1998). Secondary prevention strategies, involving screening programs that assess iron status, are directed at early identification of infants at risk for IDA. Universal screening programs are not part of routine infant health care in industrialized countries, nor are they judged to be necessary given the evidence of low anemia rates among the general pediatric population (Feightner 1994; U.S.Preventive Services Task Force 1996). However, secondary prevention is considered warranted for high-risk subgroups in an effort to diagnose and effectively treat infants. Targeted screening of these high-risk subgroups has been implemented on a national scale in the United States. However, in the United Kingdom and Canada targeted screening programs are regionalized—only reaching high-risk infants living in very few, specific settings. Given the uncertainty of whether the cognitive deficits associated with iron deficiency are fully reversible, primary prevention efforts deserve public health attention.

(a) Primary prevention

Iron-fortification of infant food has been shown to be effective in the prevention of IDA (Daly et al. 1996; Moffatt et al. 1994; Sawchuk et al. 1998; Walter et al. 1993) (refer to discussion in section 2.2 (c)-(iv)). In industrialized countries, the provision and consumption of this food (i.e., formula, cereal and biscuits) and iron-fortified formula in particular, has been the cornerstone of primary prevention efforts. National infant feeding guidelines, which are similar among industrialized countries, advocate breastfeeding for 4-6 months of age or iron-fortified formula if not breastfeeding, the delayed introduction of unmodified cow's milk during the first year, as well as the introduction of iron-fortified infant cereals around 6 months of age with continued use of this food until 2 years (Canadian Paediatric Society et al. 1998; Fomon 2001). However, these messages are not targeted directly to the needs of infants at-risk for IDA. In the United States, WIC provides iron-fortified infant formula to those choosing not to breastfeed, cereal, and iron absorption-enhancing food (i.e., vitamin C-rich juice) for low-income eligible families with infants at nutritional risk (Ponza et al. 2004). It has been estimated that almost one-half of all U.S. infants may benefit from this program (Ponza et al. 2004). In other industrialized countries such as the United Kingdom, Canada, Australia and New Zealand, there are no national programs that provide these food items directly to infants at-risk for IDA. However, in Canada, the province of Quebec offers subsidies to families receiving social assistance for the purchase of iron-fortified formula or to support breastfeeding.

The use of iron supplementation (i.e., drops, pills) in the prevention of infant IDA in industrialized countries has been limited. The efficacy of this prevention strategy has been recently assessed in a randomized, placebo controlled trial in Swedish and Honduran breastfed infants (Domellof et al. 2001). Iron supplementation had no effect on the reduction of IDA prevalence in the Swedish group. However, these infants had low IDA prevalence at baseline. The preventive effect of iron supplementation was found with the Honduran infants receiving either short or long-term supplementation (Domellof et al. 2001). Although the efficacy of this prevention strategy is positive, there are several limitations to its effectiveness. First, iron supplementation is considered a short-term strategy (Food and Agriculture Organization of the United Nations 1997). As well, this strategy depends on the adequate distribution of the supplement to the target group and the adherence of the target group to the supplementation protocol (Food and Agriculture Organization of the United Nations 1997). Furthermore, this strategy is more appropriate where access to iron-rich or iron-fortified complementary food for infants is neither available nor affordable (Zlotkin 2003). This is the situation mainly in developing countries—where cost and provision of these food items may be prohibitive.

Food based approaches, which have also been referred to as dietary diversification strategies, involve the promotion of local micronutrient-rich food sources as well as the promotion of dietary modification to improve micronutrient bioavailability of locally consumed diets (Howson et al. 1998). Implementation of this strategy has occurred primarily in developing countries and has received limited attention in industrialized countries. However, both iron-fortification and food-based approaches have been recommended as primary prevention strategies for situations, such as industrialized countries, where selected groups within a population are affected by mild to moderate IDA (Howson et al. 1998).

The effectiveness of food-based approaches in preventing vitamin A deficiency has been investigated in studies from developing countries (De Pee et al. 1998; Faber et al. 2002b; Favin & Griffiths 1992). In Indonesia, the promotion of egg consumption was shown to be effective in increasing serum retinol levels of community members (De Pee et al. 1998). Similarly, Faber et al. (2002a) found that the promotion and implementation of a home garden program was effective in increasing vitamin A intake in a rural community in South Africa. The bulk of evidence supporting the use of food-based approaches does not come from scientific investigations, but rather from reports produced by non-governmental organizations involved in the interventions (Favin & Griffiths 1992). Although, these reports do not produce the same accepted level of scientific rigour, they do give good indications of the relative effectiveness or feasibility of these types of interventions within a community setting. In developing countries, access to iron-rich food sources such as iron-fortified food or animal source food is limited. Therefore, the potential for food-based strategies to improve iron nutrition have been limited to studies investigating dietary modification to improve iron bioavailabiltiy (Gibson & Hotz 2001).

Key to the success of food-based approach strategies has been the use of carefully planned communications strategies to promote locally available food, dietary modification techniques or to increase awareness of the magnitude of the deficiency in the community. A lack of access to iron-rich food is often not the only limiting factor in the development of iron deficiency. Poor demand for and inadequate consumption of available iron-rich food also contribute to the problem (Food and Agriculture Organization of the United Nations 1997). Communication strategies are effective in creating a demand for improving the micronutrient quality of the diet as well as removing barriers to adopting new dietary behaviours (e.g., challenging existing misconceptions or beliefs) (Howson et al. 1998).

The important components involved in the use of communication strategies directed at public health interventions are illustrated in Figure 2-6. Three significant components

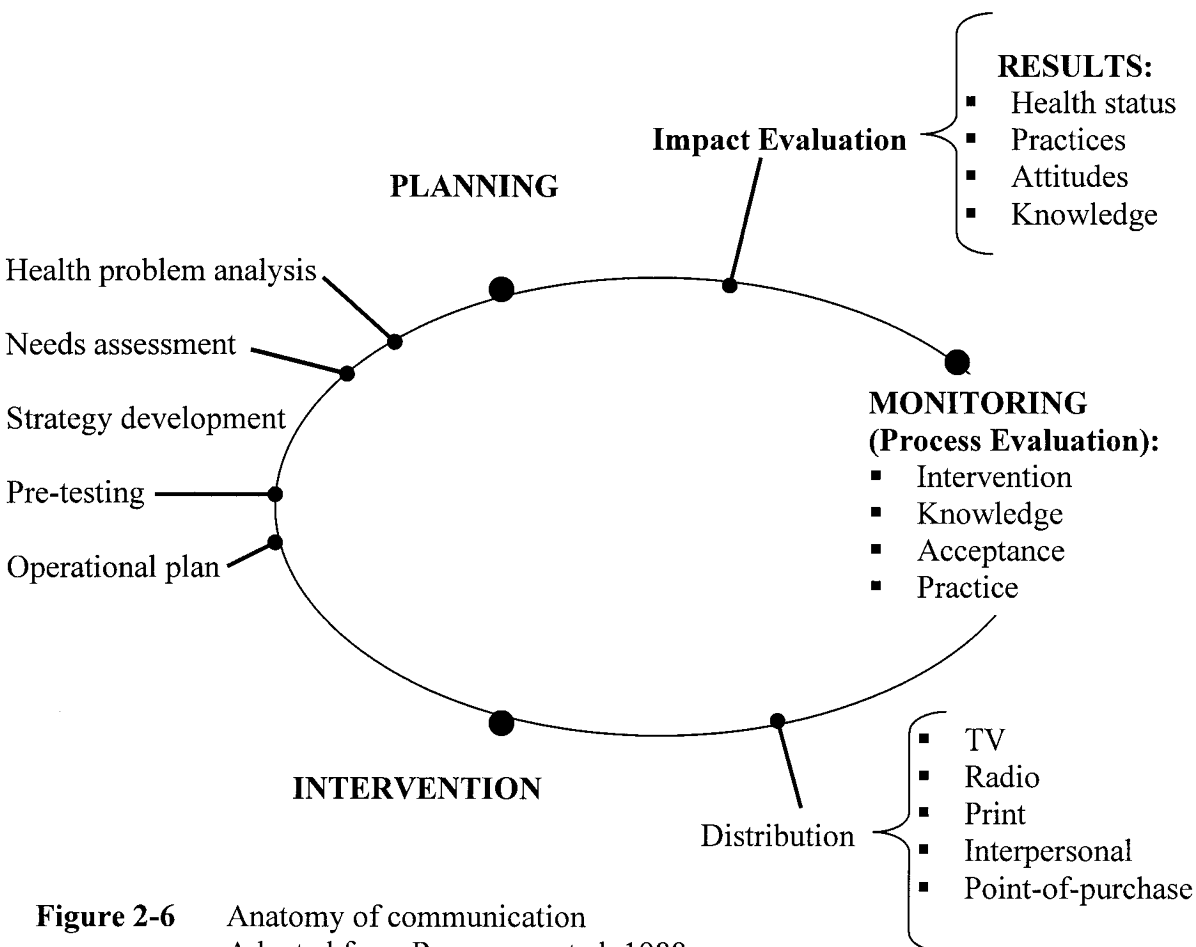

Figure 2-6 Anatomy of communication
Adapted from Rasmuson et al. 1988.

can be inferred from this model: planning, implementation (intervention) and monitoring (evaluation). Effective planning includes an analysis of the health problem (e.g., prevalence of IDA), the factors that may contribute to the problem (e.g., adequacy of iron-rich food supply, iron intake, and beliefs about infant feeding practices), the collaboration of members of the target audience in the development of communication messages, and the identification of effective communication channels. The implementation of the intervention should occur within existing community programs to enhance sustainability. Finally, the use of process evaluation is imperative to monitor the implementation of the intervention (e.g., reach and exposure of the messages) as well as an evaluation of the interventions impact (e.g., measurement of dietary behaviour change in response to the intervention or improvement in health status) (Griffiths 2002; Rasmuson et al. 1988; UNICEF/UNU/WHO/MI 1998).

In industrialized countries, there are no data regarding the effectiveness of using a food-based approach in ID prevention among at-risk infants. Perhaps, this research gap is due to the widespread belief that targeted iron-fortification of infant food and the consumption of iron-fortified formula have provided an appropriate solution to this public health issue. In the United Kingdom, the use of individual nutrition education targeting infants at-risk for IDA, living in lower SES neighbourhoods has been studied with mixed results (Childs et al. 1997; Griffiths et al. 1995; James et al. 1989). Two of these studies indicated that the use of "health visitors" to administer iron-specific nutrition information to caregivers of at-risk infants were effective in lowering the prevalence of IDA (Griffiths et al. 1995; James et al. 1989). However, Griffiths et al. (1995) had a small sample size, only 25 out of 34 infants completed the study. As well, these researchers were unable to show a concomitant rise in total iron intake, although iron status indicators improved in the intervention group (Griffiths et al. 1995). Childs et al. (1997) investigated a cohort of 1000 infants who were randomized at 6 weeks of age to a control group, receiving the typical general nutrition education available in public health clinics or the intervention group, who received additional specific information about iron nutrition at 3, 6 and 9 months of age. At 18 months of age, no significant differences were found between the two groups with iron status indicators and no differences in dietary risk factors were observed (Childs et al. 1997). Unfortunately, this study had a considerable loss to follow up, only 45% of infants completed the study (Childs et al. 1997). These researchers stated that nutrition education, particularly individual counselling, is insufficient in changing iron-related infant feeding practices and that additional factors such as environment (e.g., local food supply, infant feeding beliefs) must be considered in developing interventions. Moreover, community-based strategies targeting at-risk groups might be more successful, because they provide a more ecological approach (Childs et al. 1997).

The 55th World Health Assembly (2002) passed a resolution regarding the global strategy for infant and young-child feeding that has urged countries to ensure that the introduction of any intervention to prevent micronutrient deficiency does not undermine support for the practice of exclusive breastfeeding and optimal complementary feeding. Current efforts in industrialized countries have relied heavily on iron-fortified formula in prevention efforts with little consideration of the effect on breastfeeding practice. Although iron-fortified formula has been shown to improve IDA prevalence in at-risk groups, there is evidence from the literature that this success may be at the expense of breastfeeding practice. Breast milk is considered the optimal infant milk, providing many direct health benefits to the infant, even in industrialized countries (Kramer et al. 2001). Recent data from evaluation of the WIC program have indicated that the promotion and provision of iron-fortified formula may have interfered with breastfeeding practice (Ponza et al. 2004). Thus, the use of a food-based approach (i.e., promotion of iron-rich complementary food) may be more appropriate, because this strategy can be adapted to different cultural settings and can protect nutritionally beneficial traditional feeding practices such as breastfeeding or consumption of traditional food (Food and Agriculture Organization of the United Nations 1997). Food-based approaches are considered the ideal long-term preventive solution given that this strategy addresses the underlying cause of the micronutrient deficiency and that it promotes long-term dietary behaviour change among the at-risk group (Food and Agriculture Organization of the United Nations 1997; Howson et al. 1998). Finally, this strategy is advantageous because improvements to the overall diet can be attained, not just improvements in iron nutrition (Food and Agriculture Organization of the United Nations 1997).

(b) Secondary prevention

Early detection is an important strategy for the control of IDA in infants. Use of either universal or selective blood screening depends on the prevalence of ID in that population (Centers for Disease Control and Prevention 1998). In Canada, the Task Force for Periodic Health Examination reported that there is insufficient evidence to recommend routine universal screening by hemoglobin measurement between 6-12 months for normal risk infants (Feightner 1994). However, there is fair evidence to recommend that infants from all high-risk groups should be investigated for adequate nutritional intake and have a hemoglobin measurement between 6 and 12 months, optimally at 9 months (Feightner 1994). High-risk infants were defined by evidence of higher prevalence rates of IDA and the potential for inadequate iron intake and status. Specifically, pre-term or low birth weight (LBW) infants, infants fed only cow's milk during the first year of life, infants of low SES or of certain ethnic origin (i.e., Chinese or Aboriginal) were considered at higher risk (Feightner 1994). The Canadian Paediatric Society (2003) has also advocated that all infants between 6-8 months of age should be screened if their parents choose not to follow current feeding guidelines. At a public health level, only one regional screening program has been documented that targets an at-risk pediatric population. In 1995, Aboriginal communities from James Bay, northern Quebec instituted an anemia-screening program for all 9-month-old infants. Infants are identified with IDA through abnormal red blood cell indices from a complete blood count. Infants identified with IDA are then referred for nutritional counselling and started on a course of iron therapy. No evaluation has been conducted of this screening program. However, in practice, adherence to iron treatment and proper follow-up has been found to be inadequate (J. Morel, personal communication 2002).

American organizations suggest similar screening recommendations of high-risk infants to those in Canada (Centers for Disease Control and Prevention 1998; Kohli-Kumar 2001). However, the CDC expands their recommendations to include universal screening for all high-risk infants and preschool children between 9 and 12 months, 6 months later and annually from 2 to 5 years (Centers for Disease Control and Prevention 1998). Universal screening for IDA occurs as part of the WIC program, where hemoglobin and hematocrit levels are assessed among potential participants for nutritional risk and program eligibility. However, researchers have indicated inadequate follow-up and treatment of children identified with IDA through WIC (Kahn et al. 2002).

There are no current national recommendations for IDA screening in the United Kingdom and blood testing is recommended only as a means of monitoring the effectiveness of primary prevention (Moy & Aukett 2000). However, some physicians have attempted to implement screening programs linked to routine child health surveillance in their practices. One study found that only 63% of 21-month-old infants from lower SES and ethnic minority backgrounds were screened. Furthermore, approximately 31% of those infants identified with IDA did not adhere to treatment and follow-up (Moy & Aukett 2000). Similarly, James et al. (1997) reported a wide range of coverage (39-100%) for a screening program implemented in 4 practices. These researchers also documented evidence that an invasive blood test was not acceptable to all parents.

The success of secondary prevention strategies depends on accurately identifying individuals with IDA and on effective iron therapy (Feightner 1994). Both of these factors have limitations. Hemoglobin is considered a sensitive measurement for IDA. Nonetheless, current cut-off levels for defining IDA have been questioned, particularly for use with infants (Domellof et al. 2002a; Sherriff et al. 2001). In addition, iron therapy is effective only if the treatment protocol is adhered to. Unfortunately, there have been few studies examining the effectiveness of screening programs in industrialized countries. However, evidence suggests that adherence to iron therapy and follow-up is inadequate. Thus, current blood screening strategies used in industrialized countries may be ineffective.

Dietary intake is suggestive of iron deficiency in later infancy and early childhood (Pizarro et al. 1991) and it has been recommended as an alternative to universal blood screening for IDA (Boutry & Needlman 2001). However, current evidence suggests that this screening strategy has poor sensitivity and specificity in identifying infants at risk for IDA (Bogen et al. 2000). Thus, dietary assessment should be used in addition to laboratory testing in the identification of infants at-risk for IDA.

2.4 Summary

ID and IDA continue to be significant public health issues among certain pediatric subgroups in industrialized countries, such as infants from disadvantaged environments and ethnic minorities. Inadequate iron intake has been suggested to be the primary risk factor for developing iron depletion in infancy. Poor psychomotor skills, cognition and behavioural disturbances have been associated with infant IDA and may not be reversible with iron treatment. Secondary prevention strategies provide evidence of the magnitude of IDA among specific population groups, but screening is limited by the accuracy of diagnosis and compliance with iron therapy.

Given the limited effectiveness of secondary prevention strategies and the possibility of irreversible adverse effects with infant IDA, primary prevention is imperative. In particular, food-based approaches appear to be a promising strategy that have been successfully implemented in developing nations, but have yet to be investigated in an industrialized country setting. The following chapter examines the feasibility of implementing this strategy in a community with infants at-risk for IDA in northern Canada. Details regarding the development and implementation of the strategy are described and the results of the process evaluation are presented.

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CHAPTER 3. COMMUNITY-BASED COMMUNICATION STRATEGIES TO PROMOTE INFANT IRON NUTRITION: A SUCCESSFUL PROCESS

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3.1 Abstract

Objectives: To evaluate the development and implementation of communication strategies to promote iron nutrition for infants at-risk for iron deficiency anaemia (IDA), in a remote northern Canadian community.

Design: Key-informant and group interview methods were used to conduct a needs assessment with mothers of infants aged 3-10 months. Mass media (i.e., radio dialogues, key messages, posters, pamphlets, point-of-purchase grocery store display) and interpersonal (i.e., homemade baby food cooking activity) strategies were developed in collaboration with community members. The strategies were implemented in partnership with an existing community program. A questionnaire was administered to a sample (n=45; response rate = 64%) post-intervention to evaluate reach and exposure of strategies. Iron-rich infant food sales promoted with grocery store display were examined pre- and post-intervention period.

Setting: An Aboriginal community, located on the Eastern coast of the James Bay in northern Quebec, Canada.

Subjects: Mothers of infants aged 3-10 months, living in the community.

Results: The use of multiple communication channels was successful in increasing awareness of IDA and bringing about self-reported increased use of iron-rich infant food. Radio was the most successful channel for reach and exposure of messages. Iron-rich infant food sales increased from pre- to post-intervention ($p<0.05$). Breadth of exposure to cooking activity was more limited. However, participants reported increased confidence in preparing homemade baby food and self-reported intent to continue with this new behaviour.

Conclusion: Communication strategies that promote a food-based approach, including breastfeeding, to prevent infant IDA can be successfully implemented in a community where access to iron-rich infant food is available.

3.2 Introduction

The prevalence of iron deficiency anemia (IDA) among infants from industrialized countries has declined in recent years. Rates of 2-4 % compared to 6-8% IDA, nearly twenty years ago, have been reported (Greene-Finestone et al. 1991; Hercberg et al. 2001; Male et al. 2001; Yip et al. 1987a; Yip et al. 1987b; Zlotkin et al. 1996). Improvements in iron fortification of infant food and infant feeding practices as well as preventive programs that promoted and provide these foods (e.g., Special Supplemental Food Program for Women, Infants and Children – WIC) have been attributed to the decline (Sherry et al. 2001; Yip et al. 1987a).

Despite the reported successes, IDA continues to be a major public health problem in certain minority subgroups, with prevalence rates that approach rates reported from developing countries. Studies from the United Kingdom have reported prevalence rates of 25-40% among socioeconomically disadvantaged and certain ethnic populations of infants and young children (Booth & Aukett 1997). In Canada, an IDA prevalence rate of 25% was documented among disadvantaged infants (Lehmann et al. 1992). Canadian Aboriginal infants and young children are at particular risk, with reported IDA prevalence rates of 11-35% (Hodgins et al. 1998; Sawchuk et al. 1998; Willows et al. 2000). This rate is much higher than non-Aboriginal Canadian children, who have documented rates of 3-7% (Greene-Finestone et al. 1991; Innis et al. 1997; Zlotkin et al. 1996).

These elevated prevalence rates are an indicator that IDA should be considered of high public health significance among the affected population groups (Howson et al. 1998). Moreover, increasing evidence from the literature has shown a consistent association between IDA and psychomotor, cognitive delay, as well as, behavioral disturbances in infants and children (Hurtado et al. 1999; Idjradinata & Pollitt 1993; Lozoff et al. 1987; Lozoff et al. 1996; Lozoff et al. 2000; Walter et al. 1989).

There have been few efforts to research and document effective prevention strategies for early childhood IDA. Three main approaches include iron supplementation, iron-fortification of infant food, and food-based approaches to promote iron-containing complementary food (e.g., red meat, fish and poultry) or increase iron bioavailability in the diet (Zlotkin 2003). No single approach will be successful for all populations and in all situations. However, food-based approaches and food fortification are recommended to address iron deficiency in populations where there is mild and clustered deficiency—such as in industrialized countries (Howson et al. 1998).

Communication strategies can effectively promote both fortified and naturally occurring high-iron infant food. These strategies, such as those that are part of a social marketing approach, aim to generate consumer demand for improved micronutrient status, to increase selection of iron-containing food, and remove barriers to adopting optimal iron infant feeding practices (Griffiths 2002; Howson et al. 1998). Communication strategies used in developing countries include food-based approaches for preventing vitamin A deficiency (De Pee et al. 1998; Faber et al. 2002; Favin & Griffiths 1992) and for promoting improved complementary infant feeding practices (Brown et al. 1998; Favin & Griffiths 1992; Guldan et al. 2000). Food-based approaches for iron deficiency prevention have focused primarily on promoting food preparation techniques to improve iron bioavailability, since incorporating highly bioavailable iron food such as meat and/or poultry is more difficult in developing countries where economic, religious or cultural factors may prevent their consumption (Gibson & Hotz 2001). However, among communities where highly bioavailable, iron-rich food sources exist, communication strategies offer a promising approach for promoting these foods in high-risk groups (UNICEF/UNU/WHO/MI 1998).

To our knowledge, there are no documented studies of communication strategies to prevent IDA in young children from at-risk communities within industrialized countries and only a few documented studies have used nutrition education. These studies have primarily used individual counseling to bring about dietary behavioural change (Childs et al. 1997; James et al. 1989)—successfully raising immediate awareness of IDA, but having little impact on feeding practices (Childs et al. 1997; Griffiths et al. 1995). Researchers have suggested a more successful education approach would be to use local media to target at-risk groups in the community (Childs et al. 1997).

The promotion of iron-fortified infant formula and food and their provision to at-risk populations through targeted nutrition programs has been the cornerstone of IDA primary prevention in industrialized countries (Daly et al. 1996; Miller et al. 1985; Ramakrishnan & Yip 2002; Sawchuk et al. 1998). While this approach presents a simple, 'attractive' option by ensuring a good source of iron for infants, it fails to address two important issues. The first issue pertains to breastfeeding promotion and protection. Several studies have provided evidence of the benefits of breastfeeding for infants (Dewey et al. 1995; Duncan et al. 1993; Howie et al. 1990); including more recent evidence that breastfeeding can decrease the risk of gastrointestinal tract infection and atopic eczema in infants during the first year of life (Kramer et al. 2001). Breast milk is an excellent source of bioavailable iron and provides exclusively breastfed healthy, term infants with adequate iron intake for at least the first 6 months of life (Dewey 2001). From approximately 6 months of age, breastfeeding along with iron-rich complementary food provides sufficient iron to meet the needs of healthy, term infants (Dewey 2001; Griffin & Abrams 2001). Furthermore, breastfeeding is part of a strong cultural tradition among Aboriginal communities in Canada, thus promoting iron-fortified formula for the prevention of IDA is inappropriate.

The second issue pertains to sustainability. Prevention efforts that focus on iron-fortified formula rather than a food-based approach to promote iron-rich complementary food will fail to provide longer-term protection. From approximately 7 months of age, an infant requires adequate exposure to a diverse diet, including different textures (e.g., meat) and flavours, to ensure a successful transition to family food. Infants dependent on iron-fortified formula for their iron source will be at risk for IDA when switched from formula to cow's milk. This is particularly troublesome, as studies from the United States have indicated that high prevalence rates of IDA persist among toddlers (Eden & Mir 1997; Kwiatkowski et al. 1999; Looker et al. 1997).

In many Aboriginal communities, breastfeeding is common and the traditional diet includes excellent sources of iron-rich wild meats, many of which were and continue to be part of infant feeding practices. Within these communities, communication strategies have the potential to successfully promote these available sources of iron. This paper examines the development and implementation of a community food-based approach to promote iron-rich complementary feeding and support breastfeeding for mothers with at-risk infants from Canada. The results of the needs assessment and process evaluation of the different implemented strategies are presented. Impact evaluation, including changes in dietary iron intake and hemoglobin values of infants are presented in a separate paper.

3.3 Background

(a) History of project

In the past decade, the Cree regional health board has recognized IDA as a significant infant health issue. Secondary prevention efforts to screen all 9-month old infants in the region were instituted in 1995. A subsequent study of these regional screening results found that 32% of infants had low hemoglobin values (<110 g/L) and 11% of these showed evidence of microcytic anemia (Willows et al. 2000). Low iron intakes from complementary food were reported to be a contributing factor to deficient iron status (Willows & Gray-Donald 2002).

Based on these findings, the 'infant feeding project' began in 1999 to implement primary prevention strategies in a pilot community. The project involved a partnership between McGill researchers and an existing federally funded community program (i.e., Canada Prenatal Nutrition Program—CPNP). All Aboriginal communities in Canada are eligible for funding through this program, which aims to improve the health and birth outcome of at-risk pregnant women and infants under 1 year of age, through nutrition counselling and support (Health Canada 2000a). To further enhance sustainability, a community person was hired and trained to assist in the project.

A research agreement was developed and signed by McGill University, the regional health board's research committee and the community band council. This agreement identified the obligations and ethical conduct for each party, in all aspects of the study. Separate ethical approval was also obtained from the Ethical Review Committee at

McGill University. All potential participants involved in the data collection were informed of the study objectives and written consent was obtained prior to interviews.

(b) Project setting

The project took place in the largest Cree community, located on the eastern coast of the James Bay in northern Quebec, accessible year round by road and air. An estimated 3100 people live in this community, with approximately 95 infants born each year (Cree Board of Health and Social Services 2003; Torrie & Moses Petawabano 1999). There are high rates of breastfeeding with 87% of mothers initiating breastfeeding, 30% of mothers fully breastfeeding at 9 months, and another 15% partially breastfeeding at 9 months (Willows N, 2003, unpublished data). Common traditional foods consumed include goose, moose, caribou, and fish. Historically, traditional infant feeding practices included the provision of traditional meats.

(c) Theoretical background

Two basic underlying concepts of current cognitive-behavioural theories/models guided the project. First, knowledge is a mediating factor for behaviour and second, knowledge is necessary but insufficient to produce behavioural change. An individual's beliefs, level of motivation, and skills as well as the environment in which they live are important contributing factors to their ability to change behaviour (National Institutes of Health 1995).

A social marketing approach guided the development, implementation, and evaluation of the communication strategies. This approach involves a needs assessment to identify the target audience, their current behaviour and underlying beliefs, the environmental factors that may prevent or facilitate their behavioural change as well as the influential communication channels for message dissemination. Next, objectives are set and key messages and materials are developed with input and review from the target audience. Finally, these materials and messages are implemented and evaluated for their effectiveness. The evaluation provides feedback for program improvements (Brown et al. 1992; National Institutes of Health 1995). The strength of this approach is that it is "consumer-driven"; that is, program design and implementation are based on the expressed preferences and values of the target audience. In addition, significant consideration is given to the potential effect of the environment around the behavioural decision. Examination of the target audience's environment ensures that tailored messages reflect the practical realities of behavioural change (Brown et al. 1992; National Institutes of Health 1995).

3.4 Process

(a) Needs assessment

Individual and group interviews as well as direct observation were used to collect the data for the needs assessment (Table 3-1). Multiple methods provided different perspectives from community members, allowed for a closer understanding of the issue of IDA, as well as ensured more accurate conclusions about the data. This approach to data collection, termed "triangulation", is commonly used to strengthen data obtained from qualitative inquiry. Data collected from one source, or method, are confirmed by data collected by other means (Goldberg et al. 1999).

Results of the needs assessment revealed that IDA is a recently recognized infant health issue in Cree communities. A community elder stated that IDA was uncommon and that children did not experience the same level of infant illness as today. She shared that, "we were never told our babies had weak blood whenever we took them in (for a check-up) and they were hardly ever sick." Community health nurses perceived a low awareness of IDA among parents in the community. Data collected through interviews with mothers confirmed these findings. A higher number of mothers reported they were 'unsure' what IDA was, what the symptoms were and what the consequences might be, if untreated. Causes of IDA were also not well known among mothers interviewed; 30% reported that a lack of iron-rich foods could cause IDA.

Both key informants and interviewed mothers reported that jarred infant food was offered more frequently than homemade food. Observations conducted at the grocery stores indicated that a variety of jarred infant food was available, but availability of high-iron jarred meat and broth was limited. Results from key-informant and group interviews suggested that mothers rely on jarred infant food because they have insufficient cooking experience and perceived jarred food as more convenient. However, some of the mothers interviewed expressed concern about the quality of jarred infant food.

Mothers described traditional food as more 'satisfying for baby', 'more appetizing', and that babies that eat traditional food, 'look healthy'. However, key-informants indicated that mostly older infants (i.e., 10 month or older) were offered traditional food. This differed from the earlier age of introduction for traditional food described by the elder. Suggested barriers to traditional infant food use were mothers' belief that their infant should not have traditional food before one year of age, mothers' fear that baby may choke, and limited access to traditional foods, because some families do not have members who hunt. Breastfeeding was common among mothers in the community. However, some interviewees expressed concern that the practice may be declining, particularly among younger mothers. Influential channels for communicating infant feeding information included family members, print materials, health professionals and radio/television.

(b) Development and implementation of project activities

Needs assessment results were provided to the community through radio shows, a community display and an information booklet sent to all mothers who participated in the individual interviews. A community radio phone-in show, conducted in Cree, provided feedback and confirmed that the proposed activities were of interest. Four project objectives were set: 1) to increase awareness of IDA, 2) to promote optimal iron-rich complementary food, including traditional meat, using appropriate communication strategies and channels, 3) to provide an opportunity to enhance cooking skills through making homemade baby food, and 4) to support breastfeeding. The primary target audience was parents of young infants, with the secondary target audience including the parents' extended families and community membership at large. Full implementation of activities occurred for a 6-month period from September 2002 to February 2003.

Table 3-2 summarizes the project activities. The development process began with preparation of key messages and images to be used to promote iron-rich infant food and support breastfeeding in the community. Two workshops were conducted with interested community members (n=22), predominantly mothers and grandmothers. During these workshops, participants brainstormed ideas for messages and provided illustrations of images to accompany these messages. Key-informants assisted in the final selection of the messages and illustrations. A local artist prepared appropriate artwork for the posters from the image ideas (Figure 3-1). Ten key messages were chosen in accordance with the project objectives and disseminated on posters, pamphlets, and/or on the radio.

In addition to mass media techniques, an interpersonal communication method conveyed information to the target audience about making homemade baby food. Participant recruitment occurred through various methods including a display in the community center, advertisement posters, radio announcements, and direct phoning of mothers of young infants identified through community health records. The cooking activity was first pilot tested with a group of mothers from the community and changes incorporated, based on their evaluations. Participants learned about basic food preparation, food safety, the introduction of complementary food and iron nutrition. They also prepared pureed vegetables and fruits as well as traditional meats (e.g., moose, caribou, goose). During each cooking activity, participants were encouraged to compare jarred and homemade infant food for differences in texture, flavour and appearance.

(c) Evaluation methods

A sample of the primary target audience was recruited by telephone from a list obtained from the community health clinic. This list identified mothers with infants aged 3-10 months who were living in the community during the project intervention period. To facilitate recruitment, mothers were given the option of in-person or telephone interview. During the interview, an evaluation questionnaire was administered. The interview consisted of a questionnaire designed to examine the extent to which respondents received communication strategies, as well as the extent to which participants viewed, heard, or otherwise used the materials. To decrease respondent burden, questions referred to a selection of key messages, posters, and radio dialogues. Cooking activity participants also completed an evaluation at the end of the activity.

A computer print out of monthly sales for iron-rich food items, promoted in the display, were available from one of the community grocery stores. These data were collected before, during, and after the intervention period. Key-informant interviews with those responsible for the project implementation provided further qualitative evaluation data. Quantitative questionnaire data were compiled and analyzed using descriptive statistics and infant sales data were analyzed using Student's t-test with Statistical Packages for the Social Sciences (SPSS), version 10.0 (SPSS, Inc., Chicago IL). Qualitative data were recorded and content analyzed for themes or reported as they were recorded.

(d) Evaluation results

Of 70 eligible mothers, 45 completed the evaluation questionnaire (response rate of 64%); 23 questionnaires were administered in-person and 22 were administered by telephone. The mean age of respondents was 25 ± 5 years (range 18-38 years). The majority of mothers (70%) were not employed outside the home. The mean number of years of education was 9 ± 2 years (range 5-12 years) and the mean number of children was 3 ± 1 child.

A high proportion of respondents were able to recall the key messages and results suggested that the radio was a more effective communication channel than poster or pamphlet (Table 3-3). Only 56% of respondents could recall a message that had been disseminated exclusively on a poster and none of them could correctly identify where they had seen or heard the message. However, when asked about a message that had been disseminated exclusively by radio, 94% were able to recall the message and 80% correctly identified that they had heard it on the radio.

The radio was also effective for disseminating the dialogues. Forty percent (40%) of respondents reported to have learned 'a lot' from listening to the dialogue. This finding was further supported by qualitative comments made by respondents. For example, one mother stated, "I enjoyed the radio dialogues and promotion—acting out a show makes me listen more closely to it. It's more enjoyable to hear people doing drama", and another shared, "I learned about anemia by hearing it on the radio". The intended frequency for playing the radio dialogues (i.e., at least four times per week) was successfully implemented and received, as results showed 73% of respondents reported hearing the dialogue three or more times.

The evaluation of the grocery store display showed that this was a particularly effective channel to increase awareness of iron-rich food sources and to encourage their use. For example, one mother shared that she learned about, "iron fortified cookies and cereal—I wouldn't have known there was iron in these foods if I didn't see these displays at the store". Moreover, this increased awareness appears to have led to self-reported changes in food use. Almost half of respondents reported trying a new food with their infant because of seeing the display, including traditional meats and iron-fortified cereals. Reported sales before, during, and shortly after the intervention period supported these findings (Figure 3-2). There were statistically significant increases in the mean sales of iron-fortified infant cold cereal, infant cereal (pablum), jarred meat and broth, and iron-fortified biscuits from before (February-May 2002) to the end (December 2002-March 2003) of the intervention period ($p<0.05$).

Participation in the cooking activity was modest, despite a reported higher awareness among respondents. The intended frequency of this activity (i.e., monthly event) was lower, as the project team was unable to offer sessions in December (due to the holiday season) and in January (due to a community-wide gastrointestinal flu). The activity reached 34 parents (30 mothers; 4 fathers), with an average of 5 participants per class (range 2-9). There was a slight tendency for younger mothers not to attend the activity, as only 22% of respondents 20 years or younger reported that they had attended the activity compared to 42% of respondents 21 years or older. Those attending reported a higher level of confidence about feeding infants and making homemade baby food; 75% agreed that they felt more confident knowing why it is important to start complementary food and 86% stated they felt more confident that they could make their own infant food. The majority of participants indicated their intent to make homemade infant food 'most of the time' or 'always', 57% and 30% respectively. Reported positive aspects of the cooking activity were summarized in four themes: 1) taste-testing—opportunity to taste differences between homemade and jarred infant food 2) socializing—opportunity to share with other parents 3) hands-on activity—opportunity to use equipment and make food from scratch 4) specific learning—learned about ingredients in infant food as well as the benefits and preparation of traditional meats. Negative comments included that the session was not long enough and that, for some sessions, there were too few participants.

Two main barriers to participation in the cooking activity, identified from the questionnaire, were lack of time and lack of babysitting. Members of the project team implementing the activity suggested that other barriers were competing community events, poor weather, and traditional activities such as hunting, which meant families left the community to live at their bush camps.

3.5 Discussion

This study is the first documented use of community-based communication strategies to promote a food-based approach for IDA prevention in infants from industrialized countries. Evidence from developing countries has shown that these strategies are potentially promising, particularly in communities where sources of micronutrient rich food are available and accessible. In industrialized countries, IDA remains a serious infant health issue for certain subgroups of the population. Provision and promotion of iron-fortified formula and infant cereal continues to be the basis of primary prevention. Yet, in many at-risk populations, such as infants from Aboriginal communities, there is good access to high-iron infant food such as traditional meats. Furthermore, breastfeeding may be threatened by promotion of iron-fortified formula to prevent IDA.

Several unique features of the project may have contributed to this successful process. The use of a social marketing approach ensured that communication strategies focused on the perceptions and needs of the target audience. In particular, the breadth of information obtained from various community members through the needs assessment was critical to the formation of appropriate objectives. The development of relevant messages by members of the target audience, using colloquial vocabulary, enhanced acceptance of the information. To ensure cultural acceptability, members of the target audience and a local artist created the poster images. Identified barriers to behaviour change, such as mothers' belief not to use traditional meat with younger infants, were challenged through dialogues and messages that promoted the benefits of feeding infants this excellent source of iron starting at an earlier age. The use of local expertise and resources, including the key partnership between an existing community program and the training of a local community person contributed to the success and sustainability of this project.

The project yielded considerable knowledge concerning successful communication channels for message dissemination. A key strength was the use of multiple channels to increase awareness of key messages and bring about positive self-reported behavioural change. Previous studies have shown that multiple channels of communication, such as interpersonal and mass media approaches, are effective in behavioural change (Brown et al. 1998; Hussain et al. 1997). The radio messages in particular attained a high level of diffusion in the community, increasing awareness of key messages and enhancing acceptability. It was important that they were transmitted in the local Cree language.

Another encouraging channel of communication was the grocery store point-of-purchase display. The evaluation results revealed a positive self-reported behavioural change from some mothers; further verified by increased sales of iron-rich infant food promoted in the display. The positive self-reported food choices demonstrated in this project are similar to results shown in another community study that used a point-of-purchase display (Hunt et al. 1990). Community members rely on their two grocery stores for most of their shopping needs. One factor that may impact food sales is "bulk" shopping, which can occur in the community stores prior to people leaving for hunting or to spend time in the bush. "Bulk" shopping can also happen away from the community when members travel to southern communities. However, women with newborn infants are less likely to be living in the bush for extended periods. As well, expense and time for travel to southern communities can be prohibitive for some families. Another factor contributing to the increased infant food sales over time may be an increase in the birth rate in the community. However, the birth rate was stable over the time period reported, with 82 births in 2001, 102 births in 2002, and 76 births as of November 2003 (Cree Board of Health and Social Services 2003).

Grocery store displays appear to be effective because they can influence consumers about healthier food choices in the environment where the choice occurs. However, the effectiveness of the displays may not persist once the information is removed. This suggests that consumers may be more influenced by indicators from their environment (i.e., at the grocery store) rather than relying on memory when making a food choice (Contento et al. 1995). Thus, nutrition information provided through this channel should be a continuing effort to ensure longer-term behavioural change.

The use of an interpersonal channel of communication appeared promising. Participants in the cooking activity reported increased confidence in preparing homemade infant food and self-reported intent to continue with this new behaviour. However, the breadth of exposure to this activity was limited, especially among mothers less than 20 years of age. The low participation appeared to be due to barriers such as lack of time and babysitting, as opposed to lack of recruitment effort. Target audience segmentation by mother's age prior to our needs assessment may have revealed different needs and perceptions among younger mothers and led to a different recruitment or program approach for his subgroup. This limitation is important to note, as the reported teenage pregnancy rate among Aboriginal youth is four times higher than the national (Canadian) rate. Furthermore, the pregnancy rate in younger (less than 15 years of age) First Nation adolescent girls, living on reserves is 11 per 1000 live births compared to 0.6 per 1000 live births in the general Canadian population (Health Canada 2000b).

3.6 Conclusions

Studies are warranted to explore the effectiveness of IDA primary prevention strategies that will promote optimal intake of high-iron complementary food and encourage breastfeeding. Communication strategies to promote a food-based approach in preventing IDA present a promising and novel approach. The current study has shown that this process can be successfully implemented in a community where access to iron-rich infant food is available. However, further studies are required to verify that this approach is feasible in other communities with infants at risk of IDA.

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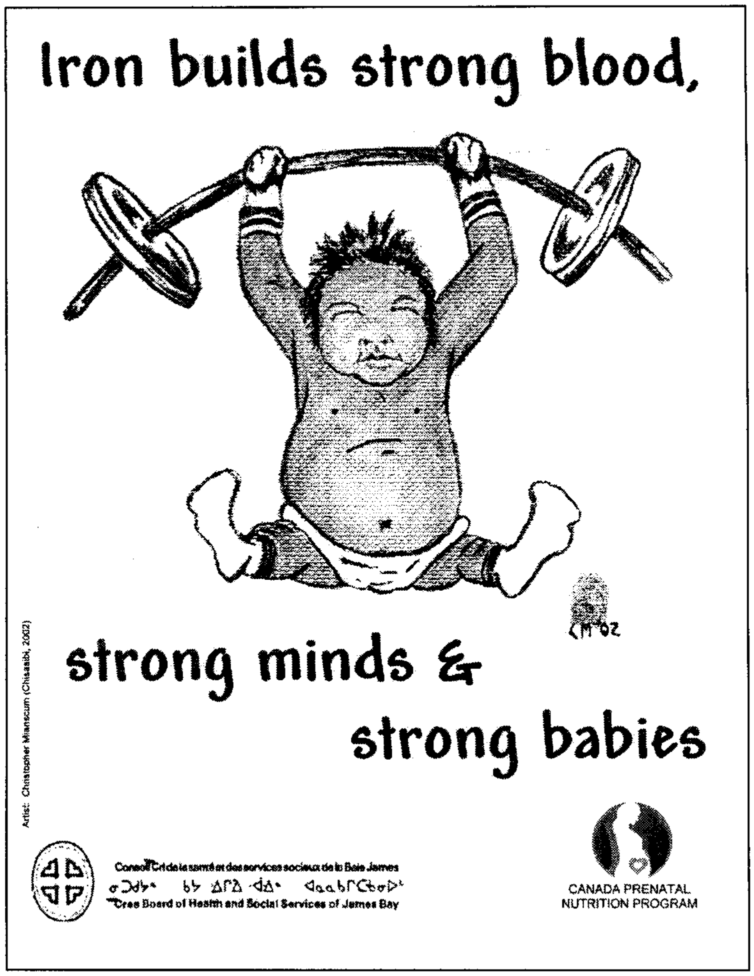
Figure 3-1 Example of final poster with key message*



* Artwork by Christopher Mianscum (Chisasibi, 2002)

Figure 3-2 Sales of iron-fortified infant foods promoted in grocery store point-of-purchase display. Data were missing for one type of iron-fortified infant biscuit. Grocery store was unable to obtain new stock of iron-fortified infant cold cereal during December.

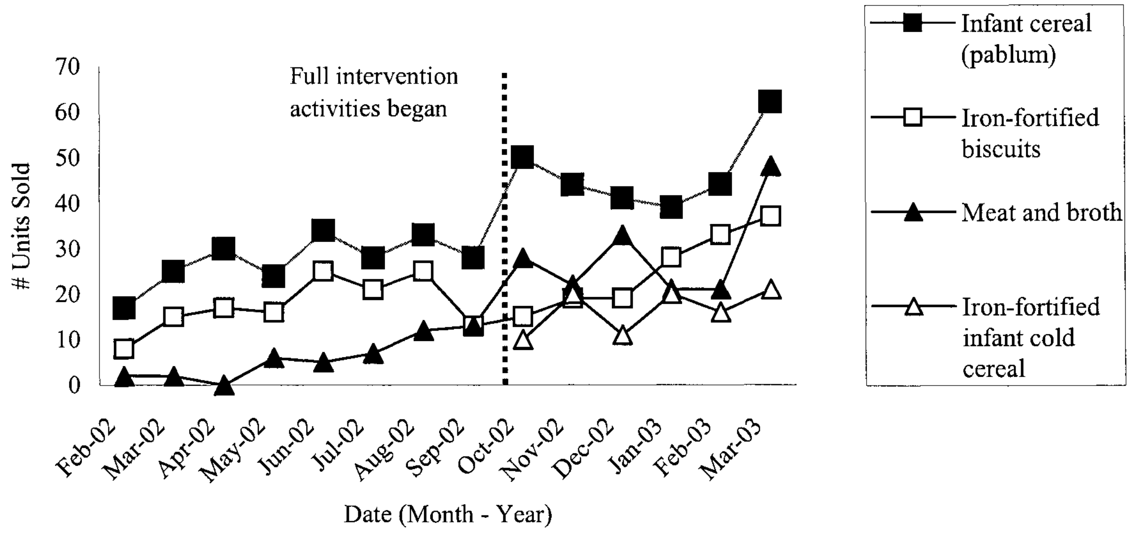


Table 3-1 Qualitative and quantitative methods for needs assessment

Methods	Instrument	Participants	Data collected
Individual interviews	Semi-structured interview guide	Key-informants (n=5): Elder, community health representative (CHR), nutritionist, band council public health officer, mother/grandmother	▪ Common infant food consumed ▪ Breastfeeding practice ▪ Traditional infant food use ▪ Community awareness of IDA / contributing factors
	Health case scenario*	Mothers with infants aged 3-10 months (n=55)	▪ Definition, cause, signs & symptoms, consequences, treatment & prevention of IDA ▪ Sources of infant feeding information†
	Self-administered questionnaire	Community health nurses (n=5)	▪ Community awareness of IDA ▪ Breastfeeding practice
Group interviews	Semi-structured interview guide	Four group interviews with mothers / grandmothers (n=23)	▪ Description of common infant food, perceived differences between infant food (e.g., differences between jarred and homemade infant food) ▪ Breastfeeding practice ▪ Importance and awareness of IDA
Direct observation	Record of food items	Grocery stores (n=2) Convenience store (n=1)	▪ List of available infant food

*Instrument consisted of a scenario depicting a mother whose infant was recently diagnosed with IDA. Each mother was read scenario and told to imagine that the woman in the scenario was asking her for information and advice. Responses to 6 open-ended questions were recorded.

†As part of demographic data collected, mothers were asked to identify key sources of infant information.

Table 3-2. Description of intervention activities

Activity or materials	Description	Target audience	Frequency	Distribution
Cooking activity*	Experiential activity to enhance cooking skills and self-efficacy with preparing homemade infant food.	Parents, extended family	Two, 2-hour sessions held once a month	School kitchen facility. Delivered by community nutrition collaborator and/or nutritionist
Pamphlets	Pamphlet #1 – Information included: basic food preparation, benefits of homemade baby food, food safety, practical tips and recipe.	Parents, community members	Supplied on continuous basis	Cooking activity, community health clinic
	Pamphlet #2 – Information included: definition IDA, sources of iron-rich food, and recipe for making pureed traditional meat.			Grocery store point-of-purchase displays
Posters	Images and key messages developed by community members and local artist.	Parents, community members	Seven different posters	Community health clinic, grocery stores, day care, arena

*Adapted from workshop manual (Lewicki 1998).

†A new iron-fortified infant cereal and biscuit were introduced in one of the grocery stores, at the request of the project team.

Table 3-2. Description of intervention activities (continued)

Activity or materials	Description	Target audience	Frequency	Distribution
Radio dialogues	Recorded by local mother in Cree and English, about following topics: ▪ IDA and infancy ▪ IDA and infancy/ promotion of traditional meats ▪ Breastfeeding promotion ▪ Homemade infant food promotion	Parents, extended family	Four dialogues played 4 times a week, at various times during the day	Free airtime provided by local radio station
Grocery store display	Point –of-purchase display that used shelf sticker and advertisements to increase awareness of IDA, encouraged use and identification of iron-rich infant food.	Parents, community members	One display per store	Infant food section of two grocery stores
Newsletter articles	Described project's development, assessment and implementation.	Parents, community members	Seven articles	Community newsletter

*Adapted from workshop manual (Lewicki 1998).
†A new iron-fortified infant cereal and biscuit were introduced in one of the grocery stores, at the request of the project team.

Table 3-3 Reach and exposure of selected communication strategies

Activity or materials	Percent aware of activity or material	Percent participating in activity, viewing, hearing or using materials*
Key message #1: "Iron builds strong blood, strong minds and strong babies."	NA†	94% recalled seeing or hearing message
Key message #2: "Know what your baby is eating; make your own baby food."	NA†	94% recalled seeing or hearing message
Key message #3: "Eating wild meat gives you energy and health."	NA†	94% recalled seeing or hearing message
Key message #4: "Breastfeeding… you carry the nutrition for your baby."	NA†	88% recalled seeing or hearing message
Key message #5: "Traditional food links our babies to our past and gives them a healthy future."	NA†	56% recalled seeing or hearing message
Radio dialogue	100%	100% recalled hearing dialogue
Grocery store display	73%	18% learned something new 45% tried new baby food
Cooking activity	91%	38% attended activity
Pamphlet #1: "The how to of making baby food"	75%	92% took pamphlet
Pamphlet #2: "Iron…helps your baby to have strong blood and to stay healthy"	88%	93% took pamphlet
Posters #1: Iron promotion	NA†	86% viewed poster
Poster #2: Traditional food promotion	NA†	79% viewed poster
Newsletter article	NA†	64% read newsletter article

* Proportion of those who were aware of activity or material.
†NA = not applicable

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LINKAGE STATEMENT

Chapter 3 presented the conceptual information for the development and implementation of a food-based primary prevention intervention. Data were collected through key-informant and individual interviews with mothers of infants from the community. Based on these findings four objectives were set: to increase community awareness of infant IDA, to promote optimal iron-rich complementary food using appropriate communication strategies and channels, to provide an opportunity to enhance cooking skills through making homemade baby food and to support breastfeeding in the community. Community involvement in developing the key messages appeared to be successful and improved the acceptability of the messages with the target audience. Radio, print material, and a point-of-purchase display were mass media channels chosen to disseminate the key messages to the target audience. As well, interpersonal communication channels were used to enhance cooking skills through a homemade baby food activity. Examples of the materials prepared for these activities are provided in appendices B to F.

Overall, results of the process evaluation indicated that multiple channels of communication were imperative in increasing message awareness and influencing positive self-reported behavioural change. The use of radio dialogues and point-of-purchase display were particularly effective. The majority of respondents were able to recall hearing the key messages on the radio and reported to have increased their knowledge regarding iron nutrition and IDA. As well, almost half of the respondents reported trying a new iron-rich food with their infant because of seeing the point-of-purchase display. This finding was supported by evidence from the mean sales of promoted iron-rich infants food items before and at the end of the intervention period. An example of the questionnaire administered for the process evaluation is provided in appendix G.

A key objective of the overall study was to measure changes in infant dietary iron intake and estimate the prevalence of inadequacy pre- and post-intervention to evaluate the impact of the intervention. In chapter 4, the results of this objective are presented.

Dietary intake data were collected from two independent groups of infants, at baseline (prior to the intervention) and 6 months after the beginning of the intervention. The methods used for dietary assessment and analyses are described and the forms used for dietary data collection can be found in appendices H and I. The mean intake of total iron and complementary food iron were determined and compared between the two groups to assess the influence of the intervention on changing infant dietary behaviour. As well, data regarding anemia prevalence and milk type consumption among 9-month-old infants in the study community and in two comparison communities were collected and analyzed.

CHAPTER 4. IMPACT OF A FOOD-BASED APPROACH TO IMPROVE IRON NUTRITION OF AT-RISK INFANTS IN NORTHERN CANADA

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4.1 Abstract

Background: We evaluated the impact of a food-based approach in promoting iron-rich complementary feeding for mothers with infants at-risk for IDA.

Methods: A repeat cross-sectional design was used to assess the impact of communication strategies to disseminate key messages promoting iron-rich complementary food. Two groups of mothers with infants, aged 7–10 months, at Time 1 (n=32; response rate = 64%) and Time 2 (n=22; response rate=48%) were interviewed. Main outcome variables were infants' total iron and complementary food iron intakes measured by two 24-hour recalls. Secular trends in infants' hemoglobin values and milk type consumption were examined in the study community and in two comparison communities.

Results: Complementary food iron intake increased between Time 1 (3.2 ± 0.8 mg) and Time 2 (4.4 ± 1.1 mg) ($p<0.05$). In the study community, the proportion of infants with anemia (hemoglobin <110 g/L) significantly decreased from the period before (1997-2000) to during (2001-2002) the intervention, 37.2% and 14.3% respectively ($p<0.05$). No significant difference was found for this variable within the comparison communities.

Conclusions: A food-based approach, promoted in a community with infants at-risk for IDA, can positively contribute to improved intake of complementary food iron as well as provide a sustainable and relevant prevention strategy.

4.2 Introduction

Iron deficiency (ID) and subsequent anemia (IDA) remain major health issues in certain pediatric subpopulations from industrialized countries (Ramakrishnan & Yip 2002). Infants and young children from socioeconomically disadvantaged environments and certain ethnic populations have been shown to be at-risk, with reported IDA prevalence rates ranging from 10-40% (Booth & Aukett 1997; Eden & Mir 1997; Lehmann et al. 1992; Oti-boateng et al. 1998). Within Canada, Aboriginal infants and young children have been shown to have prevalence rates much higher than those reported for non-Aboriginal Canadian children; 11-35% compared to 3-7% respectively (Greene-Finestone et al. 1991; Hodgins et al. 1998; Innis et al. 1997; Sawchuk et al. 1998; Willows et al. 2000; Zlotkin et al. 1996). A consistent association between IDA and psychomotor, cognitive delay, as well as, behavioural disturbances in infants and children points to the importance of preventing IDA (Hurtado et al. 1999; Idjradinata & Pollitt 1993; Lozoff et al. 1996; Lozoff et al. 2000).

In the past two decades, there has been an overall declining trend in IDA prevalence in the North American pediatric population (Sherry et al. 2001; Yip et al. 1987). Increased use of iron-fortified formula and infant cereal, as well as programs that promote and provide these items (Special Supplemental Food Program for Women, Infants and Children—WIC) have been associated with this trend (Sherry et al. 2001; Yip et al. 1987). This association has led to an inference that iron-fortified infant food, particularly formula, may provide sufficient protection to prevent IDA (Miller et al. 1985; Sawchuk et al. 1998). Breast milk contributes significant health benefits to the infant (Kramer et al. 2001) and from approximately 6 months of age, breastfeeding along with iron-rich complementary food provides sufficient iron to meet the needs of healthy, term infants (Dewey 2001; Griffin & Abrams 2001). There is recent evidence that the provision of iron-fortified formula for infants at-risk for nutritional deficiency may be detrimental to breastfeeding practice. Infants participating in WIC were less likely to have consumed breast milk and more likely to have consumed formula than non-WIC infants (Ponza et al. 2004). Thus, iron-fortified formula as a strategy for IDA prevention may not be consistent with the World Health Assembly resolution, "to ensure any micronutrient intervention does not replace, or undermine support for the sustainable practice of exclusive breastfeeding and optimal complementary feeding" (World Health Assembly 2002).

Food fortification and food-based approaches are recommended as strategies to prevent IDA in populations where there is mild and clustered deficiency—such as in industrialized countries (Howson et al. 1998). However, the basis for primary prevention of infant IDA in North America has been food fortification and far less research attention has been directed towards food-based approaches. A food-based approach focuses on the underlying cause of the deficiency and provides the most sustainable solution; promoting consumption of available iron-rich food sources or introducing techniques to improve the iron bioavailability of existing food sources (Howson et al. 1998). Educational and communication strategies that accompany food-based approaches are important because they can further consumers' understanding of the association between food consumed and nutritional status (Howson et al. 1998). Communication strategies are effective because they create a demand for and increased consumption of available iron-rich food, since improving access to iron-rich food alone is unlikely to improve intake (Howson et al. 1998). Finally, food-based approaches promote the importance of diet diversity (Howson et al. 1998). Successful communication strategies to promote food-based approaches have been implemented in developing countries for micronutrient deficiency prevention in young children (Howson et al. 1998). More recently, the benefits of food-based approaches to promote animal source food for improving micronutrient nutrition in developing countries have been examined (Allen 2003; Murphy et al. 2003; Murphy & Allen 2003; Neumann et al. 2003). In industrialized countries, animal source food is more readily available than in developing nations. This iron-rich food source can be promoted along with other optimal iron-rich complementary feeding practices; offering a promising prevention strategy for at-risk infants. To our knowledge, this prevention approach has not been studied among infants from at-risk populations in industrialized countries.

Despite improvements in iron-fortification of infant food in industrialized countries, subgroups of infants and young children continue to be at-risk for ID and IDA. Few studies have provided data regarding iron adequacy of infant diets, particularly among groups identified at-risk for IDA (Kannan et al. 1999; Nolan et al. 2002). Innovative primary prevention strategies are needed to promote optimal intake of iron-rich complementary food within these populations. The purpose of this study was to examine the impact of a community-based nutrition intervention that used a food-based approach in promoting iron-rich complementary feeding for mothers with infants at-risk for IDA. Specifically, the effect of the intervention on the infants' diet was measured and changes in total iron and complementary food iron intake were investigated.

4.3 Methods

(a) Study design and setting

The study was conducted in a community located on the eastern coast of the James Bay in northern Canada, accessible year round by road and air. This community is the largest of nine Cree First Nations communities in the region, with an estimated 3100 people and approximately 95 infants born each year (Cree Board of Health and Social Services 2003; Torrie & Moses Petawabano 1999). There is a strong tradition of breastfeeding in this community with 87% of mothers initiating breastfeeding and 30% of mothers continuing breastfeeding at 9 months (Willows N., 2003, unpublished data). Secondary prevention screening for anemia, of all 9-month old infants in the region, was instituted in 1995. A recent study of these screening data found anemia (<110 g/L) in 32% of infants and a corresponding prevalence of microcytic anemia in 11% of infants (Willows et al. 2000). Inadequate iron intake from complementary food was reported to be a contributing factor to deficient iron status among Cree infants (Willows & Gray-Donald 2002). The current study was initiated to develop and evaluate an appropriate primary prevention strategy in response to these findings.

The impact of the intervention on infants' dietary behaviour was evaluated by repeat cross-sectional interviews conducted in the study community with two separate groups of mothers at Time 1 (July-November 2001) and Time 2 (November 2002-March 2003). A sample size of 30 subjects per group was calculated, so that if the standard deviation were as high as 5 mg, there would be sufficient power (0.80) to detect a difference of 2.6 mg of total iron intake. The study design was chosen for two main reasons. First, to prevent an effect of increasing infant age, a new group of mothers who had infants of the appropriate age range were recruited for Time 2. Both groups of mothers were representative of the primary target audience and had adequate exposure to the full intervention. Second, an appropriate comparison community could not be identified within the region and, therefore, was not included for the impact evaluation of iron intake. Most communities were too small and the use of traditional as well as market food, including formula, varied importantly among the larger communities. Finally, contamination of the intervention would have been likely due to frequent travel between communities.

(b) The intervention

Details of the intervention's development and implementation, as well as process evaluation are presented elsewhere (Verrall et al. 2004). Briefly, mass media and interpersonal communication strategies were used to disseminate key messages within the community. These dissemination strategies included a series of homemade baby food cooking activities—conducted using facilities at the local school, a point-of-purchase grocery store display—in the two local grocery stores, radio dialogues—broadcast on the community radio station (i.e., local programming only), posters, newsletter articles and pamphlets. The messages, and accompanying images, were developed in collaboration with key informants and community members. They were aimed at increasing awareness of IDA; promoting optimal iron-rich complementary food, including traditional meat; promoting the benefits of homemade baby food; and supporting breastfeeding.

To enhance sustainability of the intervention, a partnership was formed with an existing community-based nutrition program. A local community person was hired and trained to conduct research as well as coordinate intervention activities. The intervention occurred in a community setting. Therefore, the community membership at-large was exposed to the prevention strategies. However, the primary target audience was community members who were parents of young infants. All intervention activities were fully implemented from September 2002 – February 2003.

(c) Participants

The impact evaluation focused on mothers of infants aged 7-10 months of age, the age when complementary food becomes an important part of the infant diet. Lists of potentially eligible mothers were obtained from the community health clinic for both Time 1 and Time 2 data collection periods. In both data collection periods, eligible mothers were Cree women, living in the community, with an infant of the appropriate age that was born in the community. All participants were recruited by telephone. Ineligible participants included mothers of infants with serious congenital anomalies or genetic conditions that would influence dietary intake, as well as infants with very low birth weight (less than 1500 grams).

Ethical approval was obtained from the Ethical Review Committee at McGill University. In addition, the Cree regional health board's research committee, the community band council and McGill University prepared and signed a research agreement. This agreement outlined the obligations and ethical conduct of each party, in all aspects of the study. All eligible mothers were informed of the study objectives and written consent was obtained prior to the interviews.

(d) Data collection

Two interviews were scheduled with each mother approximately one week apart and on different days of the week. Demographic information was collected about the mother (i.e., date of birth, number of children, employment status, education level) during the initial interview. Infant data collected from medical charts, included date of birth, birth weight, as well as most recent weight and height measurements.

(e) Dietary assessment

The first author (TV), a registered dietitian, trained the local study coordinator (LN) regarding the dietary interview protocol and methodology. At each interview, mothers were asked to respond to a 24-hour recall of the infant's intake (previous day and night) including breast milk, formula, commercial infant food, table food, and vitamin/mineral supplements. Mothers were asked to provide information regarding type of food (e.g., type of formula), brand names, and details of food preparation. To maximize the validity of the dietary data, visual aids were used to assist recall. These aids consisted of: 1) a set of colour photographs illustrating commercial infant food and formula, as well as traditional food available in the community; 2) unlabeled commercial infant food jars, filled to various graduated volumes; 3) an infant bottle and cup with graded markings; 4) an infant feeding bowl with 3-dimensional generic models representing 60 ml and 90 ml volumes; 5) an infant feeding spoon with 3-dimensional generic models that represented ¼, ½ and 1 teaspoon volumes; 6) a container of commercial dry infant cereal to allow mothers to indicate amounts used.

Food and beverage data from the 24-hour recalls were coded, entered and analysed for nutrient content using the Canadian Nutrient File (CNF) and the computer program CANDAT (Godin London Inc., London, Ontario, 2000). To examine the contribution of iron from various food sources, the dietary data were categorized into 30 food groups and analyzed accordingly. Food composition data (i.e., infant formula, infant cereal and commercially prepared infant food) not available in the CNF were added to the CANDAT database from information obtained from Canadian food manufacturers. Food composition data for Cree traditional food (i.e., Canadian goose) was added using previously published information (Belinsky & Kuhnlein 2000). The intake of breast milk was not quantified directly, but was estimated by a method previously described by Greene-Finestone et al. (1991). The energy contribution from breast milk was estimated as the difference between the average energy requirement for age/weight of the infant (kcal/kg/day) and the daily energy consumed from food and non-breast milk beverages. This estimation was calculated using the infant's age; his or her most recent weight; as well as the respective average energy requirement, as outlined by Health Canada (1990). For the purposes of this study, complementary food was defined as any food or beverage other than infant formula or breast milk.

(f) Secular trends in hemoglobin values

Hemoglobin values and milk type feeding data were collected for 9-month-old infants from all available medical charts in two comparison communities, as well as the study community, to further evaluate the intervention and identify possible secular trends. These data represented a 7-year period before and during the intervention (1996-2002). Hemoglobin values were measured previously as part of the routine anemia-screening program performed on all 9-month old infants in the region. The blood samples obtained were either venous or heel prick, depending on the community and the hemoglobin values were determined directly. The milk type information had been previously recorded by the community health nurse as part of the Well Baby Clinic visit. The comparison communities were selected due to their similarity in approximate geographic location to the study community (i.e., all communities are located on eastern James Bay coast). Data from the two comparison communities were combined owing to the small numbers of infants born in each of these communities.

(g) Statistical analyses

Differences in demographic variables between groups at Time 1 and Time 2 were analyzed using Chi-squared analysis or Student's t-test. The distribution of usual nutrient intakes for energy, total iron, complementary food energy, complementary food iron and vitamin C were adjusted for day-to-day variability (within–person variation) using the statistical approach described by the National Research Council (1986). Group means of these nutrients and mean weight of food consumed in Time 1 and Time 2 were compared using Student's t-test. Regression analysis was used to control for the effect of confounding variables on the comparison of nutrient intakes at Time 1 and Time 2.

As the requirement distribution for iron is not symmetrical, the full probability approach was used to estimate the prevalence of iron inadequacy for both Time 1 and Time 2 groups. The estimates were determined using the method described by the Institute of Medicine (2001b). The prevalence estimates for both groups were then compared using Chi-squared analysis.

Hemoglobin values and milk type data were analyzed descriptively. The proportion of infants who were anemic (defined as <110 g/L) as well as the proportion of infants consuming any iron-fortified formula were calculated for the periods before (1997-2000) and during (2001-2002) the intervention. These proportions, before and during the interventions, were then compared within both the study community and the comparison communities using Chi-squared analysis. As the total population size was known, confidence intervals for the hemoglobin values were calculated using the finite population correction factor. All statistical analyses were performed with the Statistical Packages for the Social Sciences (SPSS), version 10.0 (SPSS, Inc. Chicago, IL), with the exception of the nutrient data which was analyzed using SAS, version 8.1 (SAS Institute, Inc. Cary, NC). For all statistical analyses, a p value of 0.05 was considered significant.

4.4 Results

(a) Participant characteristics

One hundred and twenty-six (126) mothers were potentially eligible for both data collection periods, of whom 96 could be contacted and 54 (56%) participated in the interviews. The participation rate for Time 1 was 64% (32/50) and for Time 2 was 48% (22/46); χ^2=2.6 (p>0.05). Participants in Time 2 were significantly older (27.9 ± 4.3 years) than non-participants (22.3 ± 4.9 years) (p<0.05), however, no difference in age was found in Time 1. The demographic characteristics for study participants and their infants are shown in Table 4-1. Infant age was almost identical in the two groups. However, mothers in Time 2 were significantly older and had more children than mothers in Time 1.

(b) Impact on nutrient and food intake

One hundred and three (103) 24-hour recalls were collected in both data collection periods. Five recalls for Time 1 were not included in the analyses due to missing information. All 44 recalls from Time 2 had complete data. To accommodate mothers' schedules and maximize participation, two first interviews and nine follow-up interviews were conducted over the telephone. No mothers completed both of her interviews by telephone.

Infants from both data collection periods were consuming complementary food. The intervention did not appear to have an effect on consumption of iron-fortified formula, as no significant difference was found between the two groups for milk type feeding. Fifty-six percent (56%) of infants from Time 1 and 45% of infants from Time 2 were reported to consume some iron-fortified formula. Two older infants (9-10 months of age) from each time period were reported to consume cow's milk. The proportion of infants reported to receive any breast milk also remained constant from Time 1 (56%) to Time 2 (55%).

All dietary and nutrient analyses included food and beverages, without vitamin/mineral supplements. Fifty-two percent (52%) of mothers from both groups reported that their infant received a supplement (i.e., vitamin A, D, and C or vitamin D only) within the last week. No infants were reported to receive an iron supplement. Mean intakes of total iron and complementary food iron are presented in Table 4-2. Intake of complementary food iron increased significantly by 37% between Time 1 and Time 2.

No significant differences were found between the two groups for mean intakes of energy, complementary food energy, or vitamin C (data not shown), although, there was a non-significant trend for energy intake to increase from the Time 1 to Time 2. Therefore, complementary food iron intake was standardized per 1000 kilocalories of complementary food energy and compared between groups. The difference for this variable remained statistically significant ($p<0.05$). Regression analysis revealed that the significant difference in complementary food iron remained when controlling for maternal age ($p<0.05$).

Figure 4-1 provides a description of food sources that contributed to the increase in complementary food iron. The food shown in this figure represents promoted items from the intervention. No statistically significant changes were seen in individual food items due to small sample size. Further analysis of the food groups showed that changes in food intake behaviour occurred in appropriate directions. In particular, the overall diet was enhanced, as evidenced by the statistically significant decrease in consumption of juice or fruit drink and commercial mixed dinner infant food ($p<0.05$) (Table 4-3).

The estimated average requirements (EAR) for iron for this age group (7-12 months) is 6.9 mg/day (Institute of Medicine 2001a). The estimated prevalence of inadequacy was 56% (95% CI=38%, 74%) for infants at Time 1 and 41% (95% CI=20%, 62%) for infants at Time 2; however, this difference was not statistically significant.

(c) Secular trends in hemoglobin values

There was an increasing trend in mean hemoglobin values of 9-month old infants from all three communities, beginning in the year before the intervention period (Figure 4-2). In the study community, the proportion of infants with anemia (hemoglobin <110 g/L) significantly decreased from the period before (1997-2000) to during (2001-2002) the intervention, 37.2% and 14.3% respectively ($p<0.05$). However, no significant difference was found when comparing this variable over time within the comparison communities.

In the study community, the increasing trend in mean hemoglobin occurred despite any significant difference in iron-fortified formula intake. No significant difference was found in the proportion of 9-month-old infants reported to have received any iron-fortified formula. However, in the comparison communities, there was a significant increase in the proportion of infants reported to receive any iron-fortified formula ($p<0.05$). Fifty-five percent (55%) of infants were reported to consume any iron-fortified formula during the period before (1997-2000) and 73% of infants during (2001-200) the intervention, indicating an erosion of breastfeeding practice in the comparison communities.

4.5 Discussion

This is the first study in an industrialized country to evaluate an intervention promoting iron-rich complementary food to improve infant iron nutrition within a community setting. In addition, this study provides important data regarding the iron adequacy of dietary intake in an infant subpopulation at-risk for IDA and uses the new Dietary Reference Intakes for this assessment (Institute of Medicine 2001a). The results show that dietary iron intake from complementary food significantly increased among infants in a community exposed to communication strategies promoting iron-rich infant food and that breastfeeding practice was not altered.

Overall, there was a high prevalence of inadequate iron intake among infants living in the study community, with almost half of infants not consuming enough iron to meet their requirements. This high prevalence corresponds with the high prevalence of anemia also found in this population. Estimates of inadequate nutrient intake are regarded as more precise when both supplement and food intake are considered (Institute of Medicine 2000). Our study focused on the adequacy of total iron intake, however, no infants in this study were reported to consume an iron supplement.

Comparisons of these nutrient intake data with other studies investigating infant dietary intake should be interpreted with caution, owing to differences in sample characteristics and methodology. The estimated prevalence of iron inadequacy for both WIC and non-WIC infant participants from the Feeding Infants and Toddlers study (FITS) (Ponza et al. 2004) were shown to be considerably lower than the prevalence of inadequacy found among infants from the present study. As well, mean iron intakes of infants from our study were considerably lower than those reported for eight-month old infants from the United States (21 ± 22 mg) (Skinner et al. 1997) and slightly lower than those found for a sample of Canadian infants, aged 6-18 months (9.5 ± 5 mg/day) (Greene-Finestone et al. 1991).

Several methods were used in this study to minimize errors in dietary assessment. Infants' dietary data were collected from mothers using two 24-hour recalls, approximately one week apart. Therefore, we were able to calculate the adjusted iron intake distribution; allowing for a more accurate estimate of the prevalence of inadequacy. Previous literature has shown that, for groups of children, a 24-hour recall provides mean intake for most nutrients comparable to 7-day food records (Persson &

Carlgren 1984) and to measured food intake (Horst et al. 1988; Iannotti et al. 1994). Furthermore, estimating group intake distributions in infants and children using data collected by 24-hour recall is well established and is considered a sound method for quantitative assessment of nutrient adequacy (Devaney et al. 2004; Institute of Medicine 2000; Skinner et al. 1997).

The accuracy of the recall data was improved by conducting the interviews in Cree, allowing mothers to express themselves more easily in their first language. As well, the local coordinator's knowledge of traditional food and preparation techniques ensured accurate estimates for intake of traditional food. Finally, portion size determination and food recall were improved by the use of visual aids. Seasonal effects on the dietary intake of infants between the two data collection periods were unlikely. Availability of market food, including commercial infant food is consistent throughout the year in the study community. Similarly, the availability of traditional food (i.e., Canada goose) is steady, as families freeze wild meat obtained during various hunting trips throughout the year

The significant increase in intake of complementary food iron of infants in Time 2 compared to Time 1 suggests that the intervention activities influenced infant dietary behaviour. These finding are consistent with the results from the process evaluation of this study. Almost half (45%) of mothers reported trying a new iron-rich food with their infant (i.e., traditional meat, iron-fortified infant cereal or biscuits), because of seeing the grocery store display promoting iron-rich infant food. As well, reported mean sales of iron-rich infant food, promoted in the grocery store, were significantly higher at the end of the intervention period compared to before implementation of the intervention (Verrall et al. 2004). Furthermore, the increase in complementary food iron intake corresponded with the finding of increased iron intake from specific food items promoted in the intervention. There was a trend for total iron intake to increase from Time 1 to Time 2, but this increase was not statistically significant most likely due to the higher variability between subjects in consumption of a concentrated iron source (i.e., iron-fortified formula). In addition, the prevalence of inadequate iron intake appeared to have decreased from Time 1 to Time 2, but the study only had a sample size with adequate power (0.80) to pick up a difference of 24%. Although a decrease in the prevalence of iron inadequacy in this community is encouraging, the proportion of infants who were not consuming adequate iron at Time 2 remained at a level that warrants continued intervention. Thus, implementation of sustainable interventions to promote optimal infant iron nutrition is imperative.

Two limitations must be considered in interpreting the results of this study. First, the evaluation design did not include a control group. Nonetheless, we defend our choice of evaluation design and argue that a randomized controlled design would not have been appropriate. Contamination could not be controlled adequately in this study, as people frequently travel back and forth between communities. In addition, recent studies have highlighted unique issues regarding evaluation design for community-based interventions, particularly among culturally defined communities (Narayan et al. 1998; Ritenbaugh et al. 2003; Rowley et al. 2000). The concept of randomization is not compatible with community interventions where community members choose whether or not to participate, nor is a controlled design compatible with a participatory approach to developing and implementing sustainable community programs (Rowley et al. 2000). Specific adherence to structured intervention protocols has been reported to decrease participation in diabetes prevention programs with Pima Indians (Narayan et al. 1998). As well, the use of a multiple cross-sectional evaluation design has been found to be an appropriate and acceptable design for examining a lifestyle intervention for Native American adolescents (Ritenbaugh et al. 2003).

A second limitation of this study was that there was no long-term evaluation component. Interventions aimed at changing behaviour can often show initial effectiveness, but maintaining behaviours over the long-term is more difficult. However, demonstrating longer-term effectiveness is more significant in studies where a "one-time" intervention has been implemented. The current study was designed to provide a sustainable intervention in the community, implemented within an existing community program infrastructure. Thus, prevention activities were provided continuously to reinforce the importance of iron nutrition for experienced mothers and to increase awareness of this issue among new mothers.

To strengthen the design of our evaluation, we included analyses of secular trends in hemoglobin values, anemia prevalence and milk-type consumption for 9-month-old infants from the study community and two comparison communities. There was a trend for hemoglobin values to increase in both the study and comparison communities before and during the intervention. However, the consumption of any iron-fortified formula did not significantly increase in the study community, but did significantly increase in the comparison communities. Therefore, factors other than increased iron-fortified formula use are likely to have contributed to the increasing hemoglobin values in the study community. In addition, the prevalence of anemia in the intervention community decreased by over a half from the period before compared to during the intervention and no effect was seen in the comparison communities. Overall, these results suggest that the health of infants (as defined by improved hemoglobin values and decreasing prevalence rates of anemia) in the study community improved and that dietary reasons for this improvement were not associated with an increase in iron-fortified formula use.

The beneficial effects of consuming iron-rich complementary food, such as meat and iron-fortified infant cereal, on iron status of infants has been demonstrated in several tightly controlled trials in clinical settings (Engelmann et al. 1998; Walter et al. 1993; Yeung et al. 1986). The current study has demonstrated the potential for promoting these food items within a community setting. Food-based approaches for the prevention of iron deficiency offer key advantages over strategies that focus solely on iron supplementation or food fortification. A food-based approach promotes the consumption of whole food, which may lead to improvements in overall dietary patterns and in nutrient intake other than iron. This was demonstrated in the current study, as infants in Time 2 consumed significantly less juice and fruit drink than infants in Time 1—an important finding considering evidence of an association between excessive juice consumption and overweight as well as displacement of other nutrient-rich food (Ballew et al. 2000). Activities to support food-based approaches, such as learning cooking skills, can have a positive impact not only for the dietary behaviour of the target group, but also on the dietary behaviour of the extended family. Importantly, a food-based approach to improve infant iron nutrition is not likely to impact breastfeeding as opposed to prevention strategies that provide iron-fortified formula. Findings from the current study have shown that breastfeeding rates in the study community before and after the intervention did not differ.

We conclude that, despite limitations in evaluation design, this study has provided good evidence of the positive impact of community-based communication strategies that promote iron-rich complementary food. The strengths of this approach include the development of sustainable and relevant interventions due to the collaboration with community members as well as the wider impact food-based approaches can have on the overall diet—rather than the "nutrient-specific" strategies of supplementation or fortification. Given the health consequences of infant IDA and the high prevalence of this deficiency among infants living in high-risk environments, sustained prevention efforts to reduce the burden of this deficiency need to be addressed through effective strategies, such as food-based approaches.

4.6 Acknowledgments

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Table 4-1 Characteristics of study participants and their infants

	Time Period 1 (July – November 2001)	Time Period 2 (November 2002 – March 2003)
Number of participants (n)	32	22
Maternal age* (years)	24.4 ± 4[a]	27.9 ± 4.3[b]
Number of children*	2.2 ± 1.4[a]	3.2 ± 1.7[b]
Education* (years)	9.5 ± 1.7	9.3 ± 1.9
Employed (n)	9	6
Infant age* (months)	9.1 ± 1.2	9.0 ± 1.1
Infant gender: male (n)	17	15

*Mean ± standard deviation
[a,b]Statistically significant difference ($p<0.05$)

Table 4-2 Comparison of usual iron intake* of Cree children from northern Quebec, Canada

Nutrient	Time Period 1 (n=32)	Time Period 2 (n=22)
Total iron intake (mg/day)	7.1 ± 4.3	8.7 ± 5.0
Iron intake from complementary food** (mg/day)	3.2 ± 0.8[a]	4.4 ± 1.1[b]

*Adjusted intake for day-to-day variability (within person variation); mean ± standard deviation.
**Defined as any food or beverage other than infant formula or breast milk.
[a,b]Statistically significant difference ($p<0.05$)

Table 4-3 Comparison of food group intake* of Cree children from northern Quebec, Canada

Food Group	**Time Period 1** Weight (g/day)	**Time Period 2** Weight (g/day)
Infant cereals	3.1 ± 4.1	6.4 ± 6.1
Jarred infant food desserts	48.3 ± 64.3	47.6 ± 80.5
Jarred infant food meat and broth	0.0	4.1 ± 14.6
Jarred infant food mixed dinners	78.8 ± 101.0[a]	30.9 ± 48.5[b]
Iron-fortified infant cookies	0.4 ± 1.7	2.1 ± 4.3
Jarred infant food fruit	33.9 ± 56.2	27.4 ± 53.3
Jarred infant food vegetables	30.1 ± 58.9	32.0 ± 56.0
Fruit	16.3 ± 30.3	21.5 ± 33.1
Vegetables	13.2 ± 27.5	7.9 ± 18.2
Juice/Fruit drink	63.8 ± 94.5[a]	10.1 ± 24.8[b]
Cow's milk	35.1 ± 89.7	17.0 ± 67.0
Traditional meat	5.2 ± 10.5	9.6 ± 19.1
Meat, fish and poultry	15.2 ± 23.5	6.8 ± 9.8
Egg	8.2 ± 15.8	3.8 ± 13.3
Legumes/Nuts	0.0	0.0
Breads, pasta and rice	24.8 ± 28.4	21.8 ± 28.3
Yogurt	19.0 ± 34.1	26.2 ± 48.6
Soup	6.8 ± 16.0	11.5 ± 25.5

*Mean ± standard deviation.
[a,b]Statistically significant difference ($p<0.05$)

Figure 4-1 Change in iron intake from food items promoted in intervention

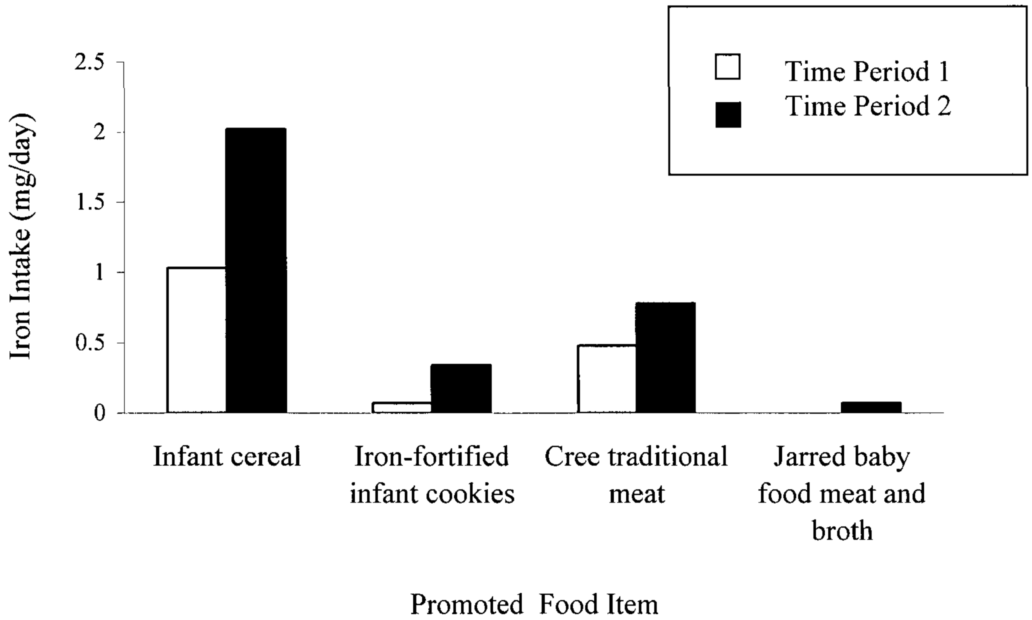
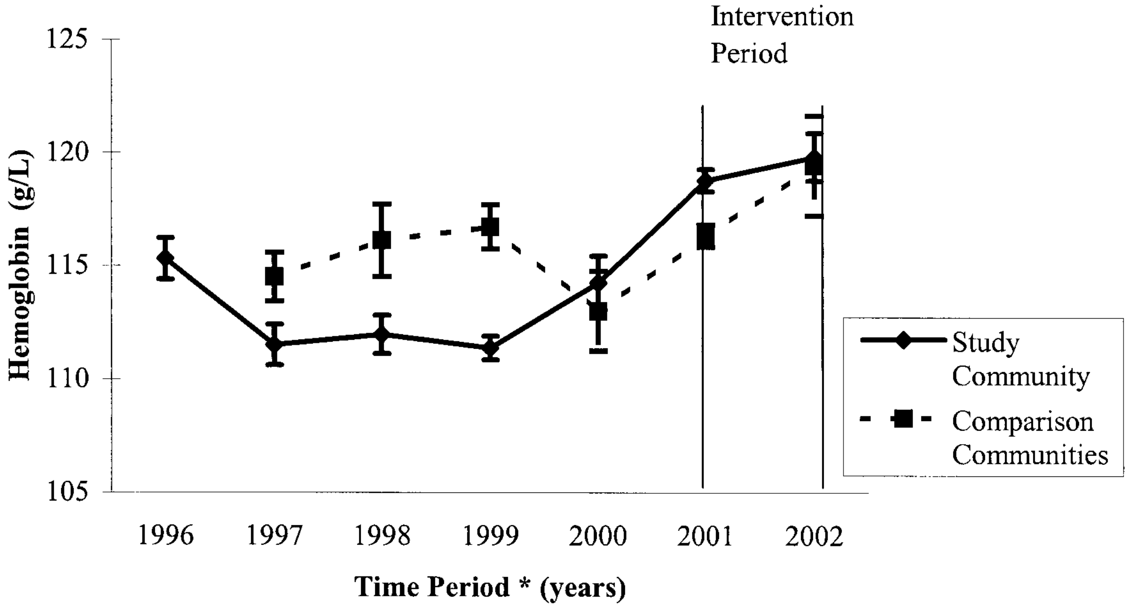


Figure 4-2 Comparison of mean hemoglobin values (95% confidence intervals) for 9-month old infants from study community and two comparison communities, northern Quebec, Canada



*No hemoglobin values available for comparison communities in 1996.

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CHAPTER 5. DISCUSSION AND CONCLUSIONS

Populations in developing countries have long been affected by widespread vitamin and mineral deficiencies. Limited access to a nutritious food supply and sub-optimal living conditions have contributed, in part, to poor nutritional status. Conversely, the notion that nutrient deficiencies exist in the Canadian population seems unlikely, unless they occur secondary to an existing illness. Canada is recognized as an affluent nation and its population benefits from access to adequate health care as well as an abundant food supply. Yet, significant health problems have been identified among the pediatric population that are related to primary nutrient deficiencies such as Vitamin D and rickets (Binet & Kooh 1996; Haworth 1995; Moffatt 1995), iron and anemia (Innis et al. 1997; Lehmann et al. 1992; Williams PL 2001; Willows et al. 2000a; Willows et al. 2000b), as well as evidence of zinc deficiency (Smit Vanderkooy & Gibson 1987). These findings are disconcerting, particularly the evidence of iron deficiency—given that Canada has universal iron fortification of infant food and formula. Currently, iron fortification is the basis of primary prevention and there have been no interventions attempting to use other strategies with vulnerable groups. Seemingly, this strategy is insufficient to prevent iron deficiency in all Canadian infants and more appropriate targeted prevention strategies warrant attention.

The experiences of non-governmental organizations and academic researchers from developing countries have contributed considerable knowledge about effective primary prevention strategies to combat nutrient deficiencies. In particular, food-based interventions have received increasing attention, because they offer a sustainable solution and have been shown to be successful in preventing micronutrient deficiencies (Ruel 2001). Unfortunately, transfer of this knowledge for use within industrialized nations has been limited, owing to misconceptions that promising strategies from developing countries are not applicable. Thus, the potential for food-based approach strategies in industrialized countries remains unexplored.

There are several reasons why food-based interventions should be considered relevant for use in industrialized countries. There are similar underlying causes of nutrient deficiencies between developed and developing countries such as food insecurity, income, and housing (Howson et al. 1998). Higher prevalence rates for IDA have been found among infants from disadvantaged backgrounds living in industrialized countries (Greene-Finestone et al. 1991; Gupta et al. 1999). In Canada, there is growing evidence of the problem of food insecurity (Badun et al. 1995) and almost one in six children still live in poverty (Campaign2000 2003). Food-based interventions from some developing countries have been successful, in part, because they attempt to resolve these underlying causes of the deficiency (Howson et al. 1998).

Experience from developing countries has also shown that food-based approaches are adaptable to different cultural and dietary traditions (Food and Agriculture Organization of the United Nations 1997). Thus, this primary prevention strategy could be beneficial for use in industrialized countries where cultural background, such as Aboriginal or Asian ethnicity, has been associated with increased risk of nutrient deficiency (Hodgins et al. 1998; Oti-boateng et al. 1998; Williams 2001; Willows et al. 2000a; Willows et al. 2000b). In particular, this strategy would benefit Aboriginal communities, where strong cultural dietary traditions need to be protected and promoted (Kuhnlein & Receveur 1996). As well, the use of food-based approaches for infants has been found to improve overall dietary intake and support breastfeeding practice (Food and Agriculture Organization of the United Nations 1997). The current iron fortification strategy used in industrialized countries is limited to increasing the intake of a single nutrient and does not contribute to overall improvements in infant feeding practice.

The present study investigated the feasibility and effectiveness of a food-based approach for promoting optimal infant iron nutrition within a culturally defined community in Canada. This research produced several important findings that have indicated the potential use of this strategy within an industrialized country setting. The results from the process and impact evaluations have underscored essential elements necessary for a successful intervention such as communication strategies, community participation, and sustainability. The importance of these elements in developing and implementing micronutrient prevention strategies have been demonstrated previously in developing countries (Howson et al. 1998).

In the present study, communication strategies were found to contribute to motivating community members to action. Social marketing techniques contributed to the development of these strategies. For example, important beliefs regarding infant feeding practices in the community, identified in the needs assessment, were incorporated into communication materials. As well, community members themselves were involved in developing the key messages and accompanying images, forming the foundation of the communication strategies. Obtaining information directly from the target audience and including them in the process of developing communication strategies have been shown to improve the acceptance of interventions (Food and Agriculture Organization of the United Nations 1997).

The importance of community participation in all phases of health promotion programs has previously been demonstrated in both developing and developed countries (Food and Agriculture Organization of the United Nations 1997; Howson et al. 1998; Macaulay et al. 1997). Community involvement not only improves acceptance of the intervention, but also helps to motivate behaviour change as well as increase ownership and sustainability of the intervention. In the present study, community involvement occurred primarily in the development of communication strategies and implementation planning. This process was shown to be both feasible and well received by community members. Ideally, the need for a prevention strategy should have come from the community members themselves. However, it was unlikely that members from the study community would have initiated concern about infant IDA, because IDA is a "hidden" health condition and, initially, there was minimal awareness of this health issue in the community.

Sustainability of an intervention refers to the continued implementation of a successful strategy as well as the continuation of a positive impact on the target audience (Howson et al. 1998). A food-based approach is often described as a sustainable strategy because the process focuses on promoting existing local nutrient-rich food, promoting methods to improve nutrient bioavailability or introducing home production of nutrient-rich food (Ruel 2001). Through this process community members become increasingly self-reliant and there is minimal dependence on an "outside" food supply or nutrient supplementation (Howson et al. 1998). Thus, continued implementation of the intervention is facilitated and sustainability is enhanced. In the present study, results of the needs assessment showed that the community had an adequate local supply of iron-rich infant food that could be continually promoted through communication strategies. As well, the partnership with an existing community nutrition program ensured that the implementation of the communication strategies would be more likely to continue after the research funding had finished. The hiring and training of a local community member also enhanced the sustainability of the intervention, such a person could continue to be a key reference person and also conduct ongoing monitoring of the impact of the intervention.

Despite reported successful experiences as well as improvements in design and implementation, progress in understanding the potential for food-based interventions continues to be limited by weak evaluation protocols and statistical analyses of findings (Ruel 2001). In general, the use of experimental designs (i.e., RDBCT) are not suitable for evaluation of food-based approach strategies as community members choose to participate in interventions and randomization is inappropriate. To overcome this, comparison groups and control for confounding factors are used to ensure that evaluation results can be attributed to the intervention and not to external influences. Current evaluation designs may be limited by inappropriate selection of a comparison group or by inappropriate control of confounding factors (Ruel 2001). Difficulties in obtaining an appropriate comparison group were demonstrated in the current study, where significant differences in infant feeding practices were found among even the most geographically similar Cree communities. As well, the ability to "control" for contamination between communities was limited, because of frequent travel between communities. Potential confounding demographic and dietary variables were collected and controlled for as part of the evaluation design. Nonetheless, the results of the evaluation from this study only indicated the plausibility that the intervention influenced infant complementary food iron intake and did not establish causality. As well, extrapolation of these results to other communities was limited because the process of developing and implementing the intervention were site specific—focusing on the needs of the study community. However, the process itself was shown to be effective and the approach taken to develop and implement the strategies can serve as a model for use in other communities.

In summary, researchers and health professionals must recognize the public health significance of infant IDA in industrialized countries. Increased monitoring of the magnitude of this health condition is required. There is a dearth of evaluative data for food-based approaches in preventing nutrient deficiency, particularly from industrialized countries. Progress in realizing the potential of this strategy has been limited by a lack of studies investigating this strategy in different community settings. Disproportionate attention has been given to the effectiveness of iron-fortified formula as a primary preventive strategy with little consideration of the impact on breastfeeding practice. This is now increasingly important since the landmark PROBIT trial showing clear health advantages of breastfeeding in industrialized countries (Kramer et al. 2001). Novel preventive strategies that support breastfeeding and improve overall infant nutrition have been demonstrated in developing countries. The current study has shown that these strategies, such as food-based approaches, are applicable and feasible in an industrialized country setting.

Future research attention should be given to examining this strategy in other community settings. As well, improving the scientific rigour of evaluation design for this strategy is needed so that findings have increased validity. Particular attention must be given to the consideration and collection of potential confounding variables and proper statistical analyses to control for these variables. Measurement of the implementation process and intermediary outcomes would be beneficial to identify specific mechanisms by which an intervention influences behaviour change. In addition, cost-effectiveness analyses are needed of food-based approaches on their own and in comparison to fortification or supplementation strategies. The potential influence of both short- and long-term costs on the sustainability of food-based approaches should be examined (Ruel 2001). These research efforts are necessary to fully appreciate the strengths and limitations of a food-based approach as well as to establish it as a well-recognized strategy to combat iron deficiency.

Importantly, this study has influenced public health policy at the federal level. The First Nations and Inuit Health Branch of Health Canada has recently initiated an infant anemia awareness campaign as part of the Canada Prenatal Nutrition Program. Both the doctoral candidate and the community member who assisted with this study have been invited to join the working group for this campaign. In addition, the doctoral candidate has been contracted to develop an evaluation framework for this campaign as well as appropriate communication materials. Initial evaluation activities will focus on measuring the impact of the campaign on increasing awareness of this health issue. However, there is the potential for future investigations of dietary behaviour changes between participating and non-participating communities.

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APPENDICES

Appendix A. Certificate of ethical approval, McGill University

Appendix B. Example radio dialogue used in intervention

__Dialogue #2__ - **Weak blood (Iron Deficiency Anemia) in babies. Voices recorded by two Cree women from study community.**

Anne: Hi Louise, I see you've brought Sarah with you to the clinic today. She sure has grown. How old is she now?

Louise: She's 5 months old. How is Jason doing? He must be about 10 months old now.

Anne: Yes, He's here for his follow-up blood test. He was diagnosed with weak blood a month ago.

Louise: Weak blood, what is that?

Anne: It means that Jason doesn't have enough iron in his blood.

Louise: How did you know it was weak blood?

Anne: I noticed he was very tired, cranky and not eating as he usually does.

Louise: So, what did you do?

Anne: Well, I wasn't sure what was wrong, but at his 9-month clinic visit his blood was tested and that's how we found out he had weak blood.

Louise: Well, is it serious? What can happen?

Anne: Jason is receiving treatment. I learned that if a baby with weak blood is not treated well, it may affect his brain development and he may have trouble learning when he gets older.

Louise: How do you treat weak blood?

Anne: Jason is taking iron drops and I'm feeding him foods that are rich in iron.

Louise: Is there a way to prevent a baby from getting weak blood?

Anne: As soon as you introduce solid food around 4 to 6 months of age, you should include foods rich in iron such as iron-enriched baby cereal. This is an important source of iron for babies.

Louise: Oh, baby cereals...are there other foods that are rich in iron?

Anne: Yes, at about 7 months of age it's good to start your baby on pureed meats. Traditional meat such as goose, moose or caribou are very rich in iron.

Louise: That's interesting...how does Jason like those foods?

Anne: Well, I feed him baby cereal everyday. I also give him pureed meat, whenever I cook some for the family. His favorites are goose hearts and liver.

Louise: Well, Jason looks great.

Anne: Yeah… the doctor says he is doing much better now.

Louise: I'll try those foods with Sarah to make sure she has strong blood.

MESSAGES:

"Iron-rich food means healthy growth, healthier blood and a healthier baby"

"Look for food labels that say, iron-fortified or iron-enriched"

Appendix C. Pamphlet distributed at point-of-purchase display

Easy steps to Iron-Rich Eating for 6 to 12 Month Olds

1. Breastfeed your baby for at least 4 to 6 months. If you decide not to breastfeed, or when you stop, feed iron-fortified formula until at least 12 months of age.

2. Introduce cow's milk at or after 12 months of age because it is a poor source of iron.

3. Introduce iron-fortified cereals at 4 to 6 months of age and <u>continue to feed until 2 years of age.</u>

4. Puréed/mashed traditional meats such as caribou, moose, and goose as well as store-bought fresh meats (beef, pork) can be started around 6 months of age.

5. When feeding non-heme foods include a vitamin-C rich food. This helps the iron go into the blood.

Iron...

Helps your baby to have strong blood

and to stay healthy

Cree Board of Health and Social Services of James Bay

Why does my baby need iron?

> Did you know?
> Babies between 7-12 months of age are growing so fast that they need more iron than an adult man.

Iron:

- Carries oxygen from the lungs to all parts of the body
- Helps build red blood cells
- Helps the brain develop

Not eating iron-rich foods may cause a baby to get *weak blood* (also called iron deficiency anemia). This means the baby does not have enough iron in his blood.

How does my baby get iron?

Before six months:
Full-term babies use iron stored in their body since birth. They also use iron from breast milk or iron-fortified formula.

> Did you know?
> Young children with iron levels below normal do not learn as well.

After six months:
Milk alone no longer gives baby the iron needed for strong blood and health. Babies are ready to eat solids and need iron-rich foods. The main sources of iron for babies are iron-fortified baby cereal and purèed/mashed meat, fish and poultry.

Babies Best Food

Breast milk is the best food for babies up to 4-6 months of age.

Iron-fortified formula is the only other milk recommended.

Cow's milk should not be given to babies before 1 year old.

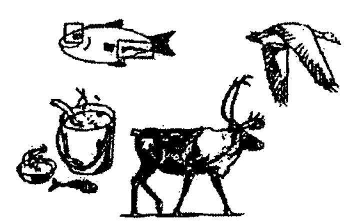
Babies Best Sources of Iron

There are two kinds of iron in foods.

1. Heme iron is the kind of iron that goes into blood most easily.

Some food with heme iron:

- Goose
- Caribou
- Moose
- Duck
- Ptarmigan
- Beef
- Pork
- Turkey and chicken (dark meat has more iron)
- Fish



2. Non-heme iron does not go into the blood as easily.

Some food with non-heme iron:

- Cereals (fortified with iron)
- Breads and pasta (whole grain and enriched with iron)
- Beans (baked or canned)
- Dark green, leafy vegetables
- Eggs

Ways to Get the Most Iron from Food

1. Go for heme:
   Meat, fish and poultry help non-heme iron from other foods go into the blood.

2. Add vitamin C-rich foods to meals.

Good sources of vitamin C:

- Berries
- Apples and its juice (vitamin C added)
- Oranges and unsweetened orange juice
- Grapefruit and its juice
- Cantaloupe
- Tomatoes, turnips, cauliflower, broccoli
- Green, yellow and red peppers
- Potatoes and sweet potatoes
- Labrador tea

> Did you know?
> Eating meat, fish or poultry and vitamin C-rich foods can increase the amount of non-heme iron that goes into the blood by up to 4 times.

How to Find Iron-Rich Baby Foods at the Grocery Store

Look for this logo on the shelves in the baby food section of the grocery stores.

Iron-rich baby food

This logo will help you find the following iron-rich baby foods:

- Iron-fortified baby cereals (e.g., Heinz, Nestle, Milupa,)
- Iron-fortified baby biscuits (e.g., Farley's, Heinz)
- "Meat and broth" jarred baby food (e.g., veal and broth, beef and broth, chicken and broth)

Try to include these foods, and other foods listed in this pamphlet, as a regular part of your baby's diet.

Making Puréed Meat for Your Baby

Purée of Meat

250 ml (1 cup)	cubed meat
125 ml (1/2 cup)	water

Suitable foods to prepare:
Caribou, moose, beef, pork, veal

Method:

- Place meat and water in saucepan and bring to a boil. Reduce heat and simmer for about 45 minutes or until meat is tender and cooked throughout.
- Remove from the heat and cool slightly.
- Blend or purée the meat (if needed add more boiled water).
- Refrigerate for up to two days. Freeze remaining purée in single servings in ice cube trays.

Tips for picky eaters:

Combine puréed meat with fruits or vegetables such as applesauce, squash, sweet potato, or any of their favorite foods.

For more information about feeding your baby, please contact:

Lucie Leclerc, Dietitian-Nutritionist, CPNP

Lily Napash – Community Collaborator

Sophie Mercure – Dietitian-Nutritionist CPNP

Tel: 855-2844 (ext. 4521 or 4522)

Adapted from:

- Iron Pamphlet - Beef Information Centre 2002
- How to prevent and treat anemia - CBHSSJB 2000

Prepared by (Sept. 2002):

- Tanya Verrall, Dietitian-Nutritionist – McGill University
- Lily Napash, Community Collaborator – Chisasibi, QC
- Sophie Mercure, Dietitian-Nutritionist – Chisasibi, QC

Appendix D. Pamphlet distributed at homemade baby food activity

THE "HOW TO" OF MAKING BABY FOOD

"A way to offer traditional food"

July 2002

Making homemade baby food

It is cheaper, fresher, and more nourishing for babies.

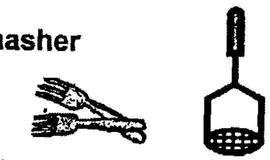
With homemade baby food, your baby can eat traditional foods like wild meat, such as goose, duck, caribou, rabbit, and fish. Babies often like organ meats like liver and heart as well.

Babies can also enjoy the taste of more kinds of vegetables and fruits.

1

What do you need to start ...

Spoon, forks and potato masher



Use these to mash soft foods, such as most canned fruits, egg yolks, bananas and potatoes to the right consistency.

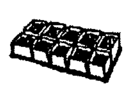
Baby Food Grinder

This can be used at home or when traveling. It is most useful when preparing cooked fruits, vegetables and soft fresh fruit.

Blender

Your blender is useful to prepare food for your baby. Food items cooked for the family can be blended smooth for baby or to freeze for later. Hand-held blenders are useful pieces of equipment that you may want to consider.

Plastic ice cube trays



Use trays for freezing extra food that you prepare. After the food is frozen, remove the cubes and store in freezer bags.

Preparing safe food for baby...

Special care should be taken when preparing food for babies. They are more at risk for getting germs than are older children and adults.

- Wash your hands with soap and warm water.

- Scrub all working surfaces with soap and hot water. Scrub all equipment with soap and hot water. Rinse well.

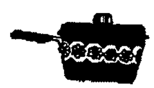
- Never let cooked food come into contact with raw food. Cutting boards and utensils that have been used with raw foods must be washed well. (You could also use separate cutting boards for raw and cooked food.)

- Do not let prepared baby food sit at room temperature for more than 2 hours. Harmful bacteria may grow in the food. Refrigerate or freeze the baby food as soon as possible.

Vegetables & fruit purees

Fresh or frozen is best. To prepare:

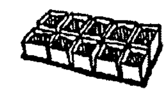
Scrub, pare or peel. Remove any seeds.



Cook in a small amount of water until tender, on the stove or in the microwave. The amount of water is important – the less water used, the more vitamins stay in the food.

Most vegetables & fruits can be pureed in a blender with cooking water or mashed well with a fork or potato masher. (Example: bananas)

Vegetables & fruit purees



Pour the puree into ice cube trays. Cover with plastic wrap and freeze in the coldest part of the freezer.

After, put frozen cubes in freezer bags, label and date the bags. Put in the freezer and keep frozen until use.

Canned vegetables and fruits do not need to be cooked. Rinse them well and puree with fresh water.

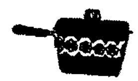
NOTE:

Use **fresh** water to puree carrots and do not give beets, turnips or spinach until your baby is 9 months old.

Why?

These vegetables contain nitrates. Nitrates occur naturally in water and soil. Normal quantities of nitrates found in these vegetables are not a problem for adults. However, for young babies, nitrates can bind to iron in the blood and make it hard for the blood to carry oxygen.

Meat, liver & fish purees



Cook in water until soft.

Puree in blender with the cooking water or milk.

Freeze and store the same way as vegetables and fruits.

Cooking Tip: For fish you can also boil it in milk.

Pureed liver and meat are very important for your baby, because they contain **a lot of iron for strong blood** and **good development**.

Liver Recipe

- 5 to 6 goose livers
- 1 cup water

Cook liver in the water for about 10 minutes. Puree the liver in a blender or food processor with some of the cooking liquid.

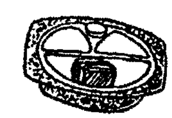
An excellent source of iron

Never add salt, sugar or seasonings to baby's food

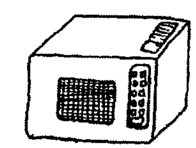
Baby does not need these for added flavour. Let your baby discover the natural flavours of food.

Thawing and warming baby's food

Stove Method: Put frozen cubes in a heat-resistant container in a pan of hot water (a double-boiler works well). Heat until warm. You can also use a plastic warming dish.



Microwave method: Microwaves heat food unevenly and cause hot spots. It is important to stir food well to prevent burns to you or your baby. Put frozen cubes in a microwavable dish. Heat on the defrost setting.



NOTE:

- It is not recommended to heat pureed meats in the microwave. Hot spots in the meat could burn your baby. Use the stove method instead.
- Allow food to sit for a few minutes and stir well. Check the temperature of the food on the back of your hand or inside of your wrist before giving it to your baby

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For more information about feeding your baby or if you are interested in participating in the homemade baby food cooking activity, please contact:

Lily Napash, Community Collaborator,
Chisasibi Prenatal Nutrition Program -
Infant Feeding Project

Sophie Mercure, Nutritionist,
Chisasibi Prenatal Nutrition Program -
Infant Feeding Project

Telephone: 855-2844
(Extension 4521 or 4522)

CHISASIBI - CLSC

Conseil Cri de la santé et des services sociaux de la Baie James
Cree Board of Health and Social Services of James Bay

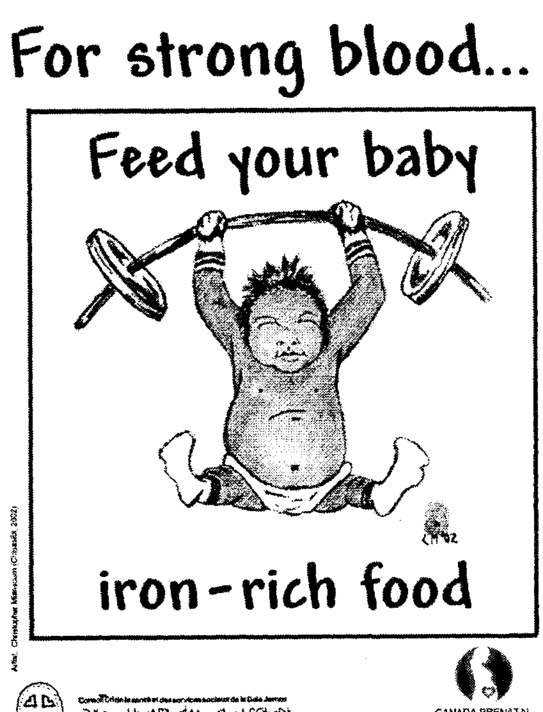
Choking Alert

Babies and children need to be supervised at snacks and/or when eating meals to prevent them from choking.

Foods that are most likely to cause choking and that are not recommended for baby:

- Whole nuts or seeds (alone or in food)
- Whole wieners (unless cut lengthwise and crosswise)
- Hard pieces of raw fruit or vegetables (carrots, celery)
- Fruit with seeds like berries
- Whole grapes and olives (unless chopped)
- Kernel corn
- Raisins
- Small candies
- Popcorn

Appendix E. Examples of posters displayed in community



Appendix F. Example of community newsletter article

Weak Blood

Understanding and preventing Weak Blood (Anemia) in Eeyou Babies of Chisasibi

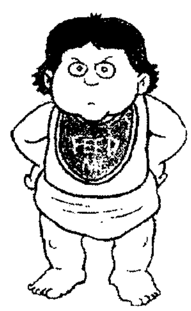
Tanya Verrall, Lily Napash
& Lucie Leclerc.

In 2000, reasearchers from McGill University reported that one out of three Cree babies screened at 9- month well-baby clinics in coastal communities had weak blood. In this study, Dr. Noreen Willows and Dr. Catherine Gray-Donald found that for many of the babies, the weak blood was mild and unlikely to affect their health. However, for one in ten babies, the weak blood was severe enough to be a health problem. Weak blood has been shown to affect babies' ability to learn when they grow older.

These researchers reported that the Cree babies with severe weak blood were likely not getting enough iron in their diet. Iron is a component found in certain foods. It has many important roles in keeping our bodies healthy.
One very important role is to keep our blood strong. How does it do this?: Iron carries the oxygen we breathe from our lungs to the rest of our body. This gives us enegy. Just like a truck is needed to deliver the materials to a construction site - iron is needed to carry oxygen all through our body.
Women, children and babies are more likely to get weak blood. Babies are more at risk, because they grow very fast and need extra iron to support their growth. There

Weak Blood

are different causes of weak blood in babies. A common cause is when a baby does not have enough iron in his diet. During pregnancy, babies store iron in their bodies. This iron supply will last them until they reach 4-6 months of age, unless they are born prematurely. After this, babies need to eat foods that contain a lot of iron such as iron-enriched baby cereal, baby teething biscuits and pureed traditional meats like goose. Babies need these foods in addition to breast milk or iron-enriched formula. If baby does not get enough of this iron, he may develop weak blood.



Weak blood is a hidden health concern. When a baby has a rash or a cough, we know the baby is not well because we can see the rash or hear him cough. However, it is hard to know if a baby has weak blood just by looking at him. Babies with weak blood are usually tired, they may not be very hungry and they can appear very pale. These babies often get many colds and infections. This is why babies have their blood tested when they are 9-months old. This blood test can tell us whether or not a baby has a weak blood so they can be treated.

Fortunately, we can prevent our babies from getting weak blood. This is the goal of the Infant Feeding Project.

By doing more nutrition information activities, we hope to help babies so they do not get weak blood. Since June 2001, we have talked to parents, health workers and elders in Chisasibi to understand what foods they think are important for feeding babies. We have completed our interviews and are in the process of sharing the information with the community. Our next task is to recieve ideas from more people in the community and seek their participation in the future nutrition activities. Another step will be to evaluate how well these activities promote good nutrition for babies. Also, we will assess what the community thinks of these activities.

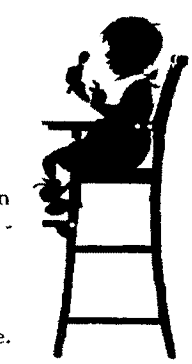
The Infant Feeding Project is supported by the following organizations: the Cree Health Board and Social Services of James Bay (CBHSSJB) through the Canada Prenatal Nutrition Program (CPNP component, the school of Dietetics and Human Nutrition of McGill University, and the Cree Nation of Chisasibi. The project team morkers are: Lily Napash - Community Colloborator who divides her time between the Infant Feeding Project and the activities of the CPNP, Lucie Leclerc - Nutritionist-Dietitian and CPNP coordinatior in Chisasibi, Tanya Verrall -doctoral nutrition student working under the supervision of Dr. Katherine Gray- Donald - researcher from McGill University.

The results of the interviews will be shared with the community in various ways. These include groups sessions, displays and radio shows. Also, a booklet about the project is available for those who are interested. We are planning to have group sessions within the next month. At these sessions, we will start to work together to find ways to promote iron-rich foods for babies and to start planning nutrition activities for families in Chisasibi.

To obtain a copy of the booklet or to become involved,
Please contact:
Lily Napash - Community Collaborator (Infant feeding Project & CNPNP) - CHBHSSJB
Telephone (819)855-2844 (Ext:5348)
Office located in the Old Arena

As you are part of the solution to prevent babies from getting weak blood, we hope to hear from you!

We would like to say Thank you to the grandparents, parents and elders who participated in the interviews - without your help the project would not be possible.



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Appendix G. Example of process evaluation questionnaire

Caregiver ID Number:
Infant ID Number:

Evaluation

To improve the infant feeding project, we are interested in knowing from parents what activities they may have had a chance to attend and/or what information they may have received. We would like to know what you think about the activities and how we might make them better.

Cooking Activity

Since September of this year, we have held a cooking activity at the school, to learn how to make homemade baby food.

1. Have you heard about this cooking activity? (circle response)

Yes **No**

2 Where did you hear about this activity? (check box – may choose more than one answer)

☐ **Radio**
☐ **Poster**
☐ **Friend or family member**
☐ **Waaskimaashtaau Newsletter**
☐ **Other (please list:________________)**

3. Did you attend this activity? (circle response)

Yes **No**

If answers yes, ask questions 3a:

3a. <u>Before</u> attending this activity, did you make your own baby food? (circle response)

Yes → **If answers yes, then ask:**
Do you currently make your own baby food? (circle response)

Yes **No**

No → **If answers no, then ask:**
After attending the cooking activity, did you start to make your own baby food? (circle response)

Yes **No** (Probe: For what reasons?)

____

____

If answers no, ask question 3b, 3c and 3d:

3b. Why did you choose not to attend this cooking activity?

____

____

3c. Do you currently make your own baby food? (circle response)

Yes **No**

3d. In the future, would you like to learn about making your own baby food? (circle response)

Yes **No** **Not Sure**

4. What do you think are some of the benefits of making your own baby food?

____

____

____

Grocery Promotion

5. Where do you buy your groceries from in the community? (check box)

☐ **The Northern** ☐ **The Co-op** ☐ **Both the Northern and the Co-op**

6. When shopping at either of these stores in the past 2 months, did you see any information displayed about feeding babies? (circle response)

Yes **No**

If answers no, go to question #7.

If answers yes, ask questions 6a, 6b, 6c, and 6d:

6a. What information did you see?

____

____

6b. Was there any information from the display, which you had not been aware of before? (circle response)

Yes **No**

Probe: Please briefly describe:

____

____

____

6c. Have you tried any new foods with your baby, as a result of seeing the information at the grocery store? (circle response)

Yes **No**

Probe: Please briefly describe the food(s):

____

____

____

6d. Overall, how did you find the information at the grocery store: (circle response)

Very helpful **Helpful** **Somewhat helpful** **Not helpful at all**

Radio Dialogues

7. Do you listen to the local radio station? (circle response) **Yes** **No**

If answers no, end of interview.

If answers yes, go to question #8.

8. Where do you listen to the radio? (check box - may choose more than one response)

☐ **Home** ☐ **Office**

☐ **Car** ☐ **Other (please list):** ____________________

9. In the past 2 months, did you hear any information on the radio about feeding babies and nutrition & pregnancy?

Yes **No**

If answers yes, then ask: Please briefly describe any of the information you heard:

____

____

____

____

I will now describe to you a radio dialogue that some people recall hearing, others don't. Louise and Anne are talking about their babies in the waiting room of the clinic. Jason is Anne's 10-month-old baby and he has weak blood. Anne tells Louise about weak blood and how to prevent it.

10. Have you heard this dialogue on the radio? (circle response) **Yes** **No**

If answers no, go to question #11.

If answers yes, then ask questions 10a, 10b, and 10c:

10a. In the past 2 months, how many times have you heard this radio dialogue? (check box)

- ☐ **Once**
- ☐ **2 times**
- ☐ **3 times**
- ☐ **4 or more times**
- ☐ **Not sure**

10b. How much did you learn about how weak blood affects babies from this radio dialogue?(check box)

☐ **A lot** ☐ **Some** ☐ **Nothing**

10c. How much did you <u>like or dislike</u> this radio dialogue? (circle response)

Liked a lot	**Liked a little**	**Neither liked nor disliked**	**Disliked a little**	**Disliked a lot**

***** If answers, neither liked nor disliked, disliked a little, disliked a lot then ask: For what reasons?**

____

11. Any other comments about the radio dialogues:

____

Appendix H. Example of 24-hour recall data collection form

Caregiver ID Number:
Infant ID Number:

24-Hour Recall #2

Interviewer: LN ☐ **Interview Date:** ________________ (Year/Month/Day)	**Location of Interview:** ____________ **Date Food Eaten:** ________________ (Year/Month/Day)

Did your baby receive a vitamin or mineral supplement yesterday? **Yes** **No**

If yes, **Type** (e.g., Vitamin D) ________________

Brand (e.g., Tri-o-Vit) ________________

Dose ________________

Time of Day	Place Eaten	Food and drink, description (e.g., brand name) and cooking method	Amount Eaten (Milliliters, teaspoon, tablespoon, count)

Was food intake unusual? **Yes** **No**

If yes, how was it unusual? ________________________________

____

Appendix I. Example of food frequency questionnaire data collection form

Caregiver ID Number:
Infant ID Number:

Food Frequency List

How many days in the PAST WEEK, did your baby eat __________ (the food or drink)?

How many times A DAY does your baby usually eat __________ (the food or drink)?

Name of Infant Food	**Number Days Food Eaten Per Week (Check one per food item)**								**Times Per Day**
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	
INFANT CEREAL (iron-fortified)									
OTHER CEREAL__________________ (type, brand)									
INFANT BISCUITS ☐ Farley's ☐ Arrowroot ☐ Other __________________ (type, brand)									
FORMULA ☐ Iron-fortified ☐ Regular									
BREAST MILK									
COW'S MILK __________________ (type, brand)									
JUICE / DRINK ☐ Juice/Drink __________________ (type, brand) ☐ Tea ☐ Iced Tea									

Name of Infant Food	**Number Days Food Eaten Per Week (Check one per food item)**								**Times Per Day**
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	
<u>JARRED BABY FOOD (STORE)</u>: **MEAT WITH BROTH**									
MIXED DINNER (e.g. Vegetables & Turkey)									
VEGETABLE									
FRUIT									
DESSERT									
<u>HOME-PREPARED FOOD</u>: **EGG**									
MEAT (e.g., Wild meat or store-bought)									
CHICKEN									
FISH									
VEGETABLE									
FRUIT									

Date: ______________________