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IRON NUTRITION DURING EARLY CHILDHOOD

Factors influencing iron status and iron intake

ANN-CATHRINE BRAMHAGEN



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AKADEMISK AVHANDLING

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Abstract The overall aim of this thesis was to describe the prevalence of iron deficiency (ID) and factors influencing iron status and iron intake among otherwise healthy children. The specific aim in paper I+II was to describe the prevalence of ID among 2 ½-year-old children in relation to intake of cow's milk and follow-on formula. The design in the first two papers were cross-sectional and 367 2 ½-year-old children participated. Data collection included blood samples in order to determine the child's iron status and the parents were asked to estimate the child's intake of cow's milk and follow-on formula. The results showed that ten percent of the children were iron deficient, with or without anaemia, and received iron treatment. Transferrin receptor levels were measured and 14% had elevated levels indicating an iron need in the cell. The intake of cow's milk was significantly higher among children with iron deficiency than among those with sufficient iron status. Eleven percent of the children with ID consumed follow-on formula compared to 43% of the iron-sufficient children. The specific aims in paper III were to describe iron status, iron intake and possible influencing factors among one-year-old children. Ten percent of the participating children (n=90) were iron depleted and 2.2% had ID. Furthermore, 27% of the non-breast fed children had a daily iron intake below the Nordic Nutrition Recommendations. Twenty-five percent reported that they experienced feeding problems when the child was 12 months old and some stated that they had to manipulate the child in order to make it eat. The children with mothers reported an education ≤ 9 years had significantly lower iron intake, lower Hb and lower MCV than children with mothers who had an education > 9 years. Information about iron rich food from the Child Health Service to the parents improved the child's iron status. The specific aim in paper IV was to elucidate mothers experiences concerning feeding situations. The design was qualitative and interviews with 18 mothers were conducted. The interviews were transcribed verbatim and analysed with content analysis. Two main categories were identified, positive or negative experiences. The mothers with positive experiences trusted the child's ability to regulate food intake and they describe the child as easy to interpret. Mothers with negative experiences describe their child as petulant and felt difficulties in interpret the child's signals. They had to control the child's food intake and one way was to manipulate the child with treats or reward in order to make the child eat. In conclusion, ID still exists among healthy children in Sweden during early childhood. The children with ID drank more cow's milk than those with sufficient iron status. Fewer with ID received follow-on formula compared to those without ID. Low maternal education correlated with low iron intake. Twenty-seven percent of the children had an iron intake below recommendations. Iron fortified follow-on formula and porridge contributed with a large proportion of the total iron intake among one-year-old children. Information about iron rich food resulted in improved iron status.	
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Ann-Cathrine Bramhagen

To Mats, Therese and Henrik

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ORIGINAL PAPERS

This thesis is based on the following papers referred to in the text by their Roman numerals:

- I Bramhagen, A-C & Axelsson, I. Iron status of children in southern Sweden: effects of cow's milk and follow-on formula. *Acta Paediatr*, **88**;1333–7:1999
- II Bramhagen, A-C, Virtanen, M, Siimes, MA, Axelsson, I. Transferrin receptor in children and its correlation with iron status and types of milk consumption. *Acta Paediatr*, **92**;671–5:2003.
- III Bramhagen, A-C, Axelsson, I, Hallström, I, Svahn, J. Factors influencing iron nutrition among one-year-old healthy children in Sweden. (*Submitted*).
- IV Bramhagen, A-C, Axelsson, I, Hallström, I. Mothers' experiences of feeding situations - an interview study. *J Clin Nurs*, **15**;29–34:2006.

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ABBREVIATIONS

AA	Ascorbic acid
ANOVA	Analysis of variance
CHC	Child Health Centre
CHS	Child Health Service
CI	Confidence interval
Hb	B-haemoglobin
ID	Iron Deficiency
IDA	Iron Deficiency anaemia
IS	Iron Sufficiency
MCV	Mean corpuscular volume
NNR	Nordiska näringsrekommendationer (Nordic Nutrition Recommendations)
SCB	Statistiska Centralbyrån (Statistics Sweden)
SD	Standard deviation
SES	Socioeconomic status
S-ferritin	Serum ferritin
TfR	Transferrin receptor
WHO	World Health Organization

INTRODUCTION

Good nutrition among infants and young children is vital for optimal growth and development. The first years during childhood are a period when rapid growth and development bring special demands and require attention. Birth weight triples and birth height increases by 50% during the first year (Dallman *et al.* 1980). The growth spurt of the brain ends at about 2–3 years of age (Dobbing 1990). The relative requirements concerning iron are therefore highest in early childhood from 6 months to 2 years of age (Hallberg 2004).

For the breastfed child aged 6 months and beyond, the requirement of iron from complementary food is nearly 100% (WHO 1998). When iron intake does not meet the requirement, iron deficiency occurs. Iron deficiency is one of the most common nutritional deficiencies worldwide (Fomon 2000) and increases the risk of delayed mental and motor development (Hurtado *et al.* 1999, Lozoff *et al.* 2000).

A healthy child can regulate its intake to a certain degree, but the composition of the food is the parent's responsibility. Feeding patterns differ in families but are established during the first years and affect later feeding and the overall health of the child (Hobbie *et al.* 2000). The Child Health Service (CHS) in Sweden has an important task in preventing and detecting different kinds of morbidity in order to optimize conditions for the growing child. According to a summary from a state-of-the-art conference in 2000 (Sundelin & Håkansson), the CHS intentions to detect deviations in children should focus on health perspective including mobilization of parental skills and competence.

Despite several studies during the last 25 years regarding high prevalence of iron deficiency and its consequences, the condition still exists (Wharton 1999) and its prevention is important (Hallberg 2001). There is a lack of studies from Sweden concerning iron deficiency, its prevalence and influencing factors, which need to be elucidated so that effective prevention can be initiated and developed.

BACKGROUND

Iron deficiency

Iron deficiency is the most common nutritional disorder all over the world, affecting millions of people (DeMayer & Adiels-Tengman 1985). The aetiology of iron deficiency in infancy and early childhood is (i) decreased iron stores at birth due to premature birth, early clamping of umbilical cord, duplex; (ii) inadequate iron supply due to reduced dietary iron intake or poor bioavailability; (iii) increased iron requirements due to rapid growth (Dallman *et al.* 1980, Dallman 1984, Olivares *et al.* 1999); and (iv) increased iron losses i.e. gastrointestinal blood losses (Ziegler *et al.* 1990, Olivares *et al.* 1999). When a child moves from a condition of iron sufficiency (IS) to iron deficiency (ID) the first thing that occurs is that iron storage decreases. When iron stores are depleted the normal production of haemoglobin suffers from an inadequate supply of iron. Morad (1998) concludes from a retrospective analysis of severe iron deficiency anaemia that 88% of the cases had nutritional causes. According to Oski (1993), the evidence of iron deficiency is an increase in haemoglobin values after iron treatment, but a study by Allen *et al.* (2000) found improved iron status after iron supplementation but not higher levels of haemoglobin.

Prevalence of iron deficiency

The prevalence of iron deficiency varies widely (Table 1) partly because of different criteria used to establish the diagnosis and the age differences in the study populations (Oski 1993). Iron depletion refers to empty iron stores and is measured by S-ferritin. According to WHO (2001) criteria, the cut-off value for S-ferritin is recommended to be <12 µg/L among children under 5. Different criteria are used to define iron depletion, such as S-ferritin <10 µg/L (Looker *et al.* 1997, Hay *et al.* 2004) or S-ferritin <12 µg/L (Persson *et al.* 1998, Thorsdottir *et al.* 2003), making comparisons between studies more difficult.

A better understanding of iron metabolism is needed to be able to describe the prevalence of iron deficiency (Aggett *et al.* 2002). Determination of anaemia fails to identify patients with ID but yet not anaemic (Kohli-Kumar 2001) and multiple criteria are often used in the diagnosis (Looker *et al.* 1997).

Table 1. Prevalence of iron depletion, ID, IDA and anaemia.

Author year	Country	Age study group	Iron depletion	ID	IDA	Anaemia
Fagerli 1996	Norway	12 mo	9%		6.8%	15.1
Looker 1997	United States	1–2 years		9%	3%	
Eden 1997	United States	1–3 years	35%	7%	10%	
Persson 1998	Sweden	12 mo	26%			13%
Faber 1998	Africa	4–24 mo	43.2%			65.2%
Oti-Boateng 1998	Australia	6–24 mo		22.6%	7.6%	
Gupta 1999	United States	6 mo–5 y				34.9%
Bogen 2000	United States	9–30 mo		7%	8%	35%
Jain 2000	India	1–2 year				59.9%
Karr 2001	Australia	1–3 years	23%	9%	6%	
Male 2001	Europe	12 mo	15.6%	7.2%	2.3%	9.4%
Thorsdottir 2003	Iceland	12 mo	41%	20%	2.7%	
Nguyen 2004	Australia		19.4%	3.1%	3.9%	
Soh 2004	New Zealand	6–24 mo	18.6%	5.6%	4.3%	
Hay 2004	Norway	12 mo	10%		5%	
Gunnarsson 2004	Iceland	2 years	27%	9%	1.4%	

Consequences of iron deficiency

The newborn infant has low iron content in the brain, which may explain its vulnerability to iron deficiency (Aggett *et al.* 2002). The potential negative effects of iron deficiency may occur before Hb decreases below normal level (Hallberg 2001).

A relationship between iron deficiency in combination with anaemia and the adverse effect on the maturing brain has been investigated and negative long term effects have been reported (Lozoff *et al.* 1991). A follow-up study showed that children with severe iron deficiency anaemia (IDA) had increased risk of long-lasting developmental disadvantages even after 10 years (Lozoff *et al.* 2000). The study by Walter *et al.* (1989) concluded that, when iron deficiency progressed to anaemia, a negative influence on development appeared and persisted although treatment was

given. A lack of response to iron treatment was associated with indicators of chronic malnutrition and multiple micronutrient deficiencies (Allen *et al.* 2000). Lozoff *et al.* (2003) showed that children who were free of IDA at six months were randomly assigned to either high or low iron group and at 12 months the children differed regarding developmental testing. Therefore the conclusion was that healthy full-term infants may receive developmental and behavioural benefit from iron supplementation. The study by Idjradinata & Pollitt (1993) showed that children with IDA may have mental and motor developmental beneficence if they receive iron treatment. Iron supplementation improved motor development, but the effect was limited in children with severe anaemia (Stoltzfus *et al.* 2005). Even though no direct causal relationship between ID and development has been found, the correlation makes it important to prevent iron deficiency (Couper & Simmer 2001). In a review by Martins *et al.* (2001) no convincing evidence was found that iron treatment improved the children's test scores, but the review by Grantham-McGregor & Ani (2001) concluded that iron deficiency identified children at risk of poor development.

Prevalence of iron deficiency anaemia

The most common cause of anaemia is iron deficiency (Dallman 1984). Screening for anaemia in order to detect iron deficiency is, however, controversial (Kohli-Kumar 2001). Kwiatkowski *et al.* (1999) found that 45% of the children diagnosed with severe anaemia (Hb<60 g/L) were found incidentally. It is important to point out that the absence of anaemia does not exclude the presence of iron deficiency, and the presence of anaemia indicates that iron deficiency is relatively severe (Yip 1990). The prevalence of anaemia varies partly due to differences in the groups concerning age (Table 1). Studies aiming to determine cut-off values for haemoglobin are partly inconclusive. Proposals of cut-off values vary from 97 g/L (Edmond *et al.* 1996) to 100 g/L (Sheriff *et al.* 1999, Dommelöf *et al.* 2002) and 110 g/L (WHO 2001).

Body iron

The foetus has a high level of Hb in order to transport oxygen in uteri, and the newborn has substantial concentrations of storage iron (Hallberg 2001). The total body iron at birth is approximately 80 mg/kg (Dallman *et al.* 1980, Fomon 1993) and is relatively stable until 4–6 months. The child's requirements during this period are negligible (Oski 1993). After about 6 months when the iron stores are exhausted, the iron requirement is high due to rapid growth, especially up to 24 months, and is estimated at 100 µg/kg/day (Hallberg 2001).

The bone marrow produce erythrocytes and 2/3 of the total body iron is bound to haemoglobin (Norrby 1999). The erythrocytes transport oxygen from the lungs to tissues. When the erythrocyte has left the bone marrow it lives approximately 120 days and will then be destroyed in the spleen. The iron in the erythrocytes is

transported back to the bone marrow (Hallberg 2001). A one-year-old child is estimated to derive 70% from the reutilization of iron from red blood cells, and the iron need from the diet is therefore 30% (Dallman *et al.* 1980).

Blood tests to diagnose iron deficiency

Various laboratory tests are performed in order to detect iron deficiency. No single test except for bone marrow sample can alone verify iron deficiency. As discussed by Oski (1993), the diagnosis of severe IDA is easy but detecting mild forms is a challenge. Oski states that the most convincing evidence of ID is that haemoglobin increases after iron treatment. Looker *et al.* (1997) suggest that two parameters or more indicating ID must be fulfilled in order to confirm the diagnosis. Different methods result in different cut-off values and standardization of different methods is warranted (Hallberg 2001).

B-Haemoglobin

Haemoglobin in blood (B-Hb) is a transport protein for oxygen and a part of the erythrocyte. After birth, when Hb levels are decreased, the iron from the erythrocytes is reutilized (Hallberg 2001). The synthesis of erythrocytes is dependent on iron and if iron stores are exhausted a decrease of haemoglobin levels will occur (Olivares *et al.* 1999, Hallberg 2001).

S-Ferritin

Serum ferritin (S-ferritin) is a protein which stores extra iron. One third of the total body iron is stored intracellularly in S-ferritin. S-ferritin is found mostly in the bone marrow, the liver, the spleen and the muscles (Fomon 1993). These extra stores can be utilized when requirements are increased (Hallberg 2001). A small amount circulates in the plasma, which makes it possible to measure in order to reflect body iron stores. S-ferritin is an acute-phase reactor and in the presence of an infection the values increase and can therefore be falsely normal or high. The rise is about three times higher in the presence of an infection (Cook & Skikne 1989) and the information about recent infection should be included when examining iron status (Hultén *et al.* 1998). Before six months of age relatively few infants have S-ferritin <12 µg/L (Dewey 1998). If the dietary iron is inadequate, iron is mobilized from ferritin in order to maintain the production of erythrocytes (Dallman *et al.* 1980).

S-Iron

Iron is transported within the body by a protein, transferrin. If iron is absent, transferrin can bind other minerals. To measure the percentage of saturated transferrin, plasma iron is divided by plasma total iron binding capacity x 100. Transferrin saturation <10% among infants and children is used as a criterion for

iron deficiency. Serum iron concentrations vary during the day in the same individual, which makes the transferrin saturation vary too (Fomon 1993).

S-Transferrin receptor

Almost all cells have transferrin receptors (TfR) on the surface, and the receptor is the gateway for the iron to be able to enter the cell (Cook 1999). In the presence of iron need in the cell the number of transferrin receptors increases in order to optimize the iron uptake into the cell. A high level of TfR indicates iron depletion (Ulukol *et al.* 2004). Studies have suggested that serum transferrin receptor is a reliable and sensitive measurement of iron deficiency (Kohgo *et al.* 1987, Flowers *et al.* 1989, Skikne *et al.* 1990, Huebers *et al.* 1990, Punnonen *et al.* 1997, Feelders *et al.* 1999). TfR can distinguish iron deficiency anaemia from anaemia caused by chronic diseases (Ferguson *et al.* 1992, Dimitrou *et al.* 2000). One advantage is that serum transferrin receptor is not dependent on whether the individual has an infection or not (*ibid.*).

The study by Yeung *et al.* (1997) aimed to establish percentiles of TfR among infants aged 9–15 months. The mean concentration was 4.4 mg/L. In another study, 80% of Filipino preschoolers had TfR concentrations of TfR >8.5 mg/L (Kuizon *et al.* 1996). Unfortunately, different methods are used, making comparison between studies difficult. The differences between the kits can be attributed to uncertainties concerning the reference values (Åkesson *et al.* 1999). The conclusion from a study by Virtanen *et al.* (1999) was that age-specific reference values are needed. Several studies conclude that ratio between TfR and S-ferritin (i.e. TfR/ferritin) is an outstanding parameter in the diagnosis of iron deficiency (Punnonen *et al.* 1997, Dimitriou *et al.* 2000, Olivares *et al.* 2000, Cook 2003). The amount required when sampling blood from children is important, and McDade *et al.* (2002) showed that a minimal amount of blood, approximately 50 µL, collected on filter paper proved to be precise and agreed well with plasma TfR.

B-mean corpuscular volume

When iron deficiency is developed the mean corpuscular volume (MCV) of the red blood cell decreases. If a combination of low MCV and low haemoglobin appears, thalassaemia must be excluded.

Nutrition during infancy and early childhood

Breast milk

WHO (2002) recommends exclusive breastfeeding for the first six months and demand feeding is recommended all over the world (Manz *et al.* 1999). The iron concentration in human milk is relatively low, 0.2–0.5 mg/L but has a high bioavailability averaging 50% (Dallman *et al.* 1980). The reason for this is not known, but low protein and calcium levels and high concentration of lactoferrin have

been suggested to play a role. According to a multi-centre study in Europe only 25% were exclusively breastfed at 3 months but the breastfeeding pattern differed significantly between the centres (Freeman *et al.* 2000). According to Official Statistics of Sweden, 98% of children born in 2003 were breastfed during the first week and nearly 70 % were exclusively breastfed at the age of four months. Many regions in Sweden provide breastfeeding classes for parents to increase breastfeeding (Hedberg-Nyqvist & Kylberg 2000). Maternal confidence is shown to be a significant predictor of breastfeeding duration (Blyth *et al.* 2002). The ability to breastfeed the child reflects womanliness (Bottorf 1990) and is found to demonstrate ideas about good mothering (Hauk & Iriruta 2002). High maternal education is found to improve the duration of breastfeeding (Michaelsen *et al.* 1994, Dubois & Girard 2003). Factors influencing the duration of breastfeeding negatively are the amount of formula given at the maternity ward (Michaelsen *et al.* 1994) and the use of a pacifier (Marques *et al.* 2001).

In a study by Hotz & Gibson (2001) the mothers continued to breastfeed during the child's second year, but the interviewed mothers stated that they had introduced complementary food before the child was four months old. Mothers' recalled that the infant was not satisfied with breast milk alone and that the baby was always crying. The mean breastfeeding frequencies were 9 ± 4 at age 12–23 months (*ibid*). Sufficient iron status was more common among children who were breastfed ≤ 4 months than among those who were breastfed >4 months (Oti-Boateng *et al.* 1998).

Formula

In commonly used industrialized food there are insufficient amounts of iron for children. Studies have shown that follow-on formula provides an acceptable vehicle for preventing iron deficiency (Gill *et al.* 1997, Morley *et al.* 1997, Male *et al.* 2001, Soh *et al.* 2004). Infants who received iron-fortified formula had higher levels of S-ferritin than those who did not (Singhal *et al.* 2000). In a one-year-old Ghanaian population 12% of the children receiving iron-fortified formula had S-ferritin <12 $\mu\text{g/L}$ compared to 52% among the children not receiving iron fortification (Dewey 1998).

Morley *et al.* (1999) investigated whether iron-fortified formula had any effect on growth or development, but no such effects were found. Singhal *et al.* (2000) studied whether infants receiving iron-fortified formula had a higher incidence of infections or gastrointestinal problems than those receiving low-iron formulas or cow's milk, but no differences were found.

Complementary food

According to the WHO/UNICEF report, the recommended age for introducing complementary food is approximately six months (Brown 2000). There is wide variation among different populations regarding feeding patterns (Sellen 2001). The

aim of weaning is that the child around one year should eat the same food as the rest of the family, with some exceptions (Gilbert 1998).

The Nordic Nutrition Recommendations (NNR) (2004) constitutes a scientific basis for preparing diets for various groups and developing nutritional guidelines. If the recommendations are fulfilled the diet will cover nearly all the children's requirements. Breastfed infants self-regulate their total energy intake when complementary foods are introduced (Cohen *et al.* 1994). The introduction of complementary foods is complex and dependent on the availability of food, nutritional knowledge and social support (Pelto *et al.* 2003). Malnutrition starts in many children (WHO 1998) due to a discrepancy between the content of the complementary food and the estimated requirements, which makes this period a vulnerable one. Children have a relatively high nutritional requirement and since they often consume a small amount the quality of the complementary food must be high (Lutter & Riviera 2003).

Iron is one of the most limited nutrients in the complementary foods (Hotz & Gibson 2001). Sultan & Zuberi (2003) concluded that late weaning (7.04 mo) vs. earlier weaning (4.46 mo) was the most important indicator and increased the risk of iron deficiency. Jain *et al.* (2000) showed that the prevalence of anaemia was lower among those who had received complementary foods at 4–6 months than among those weaned later. Kattelman *et al.* (2001) found no differences in iron status parameters, either in relation to early (3–4 mo) vs. late (6 mo) introduction or to the type of complementary food.

Hotz & Gibson (2001) found that the mean frequencies of complementary foods were 4.4 ± 1.4 for children aged 12–23 months. A correlation of the infant's favourite food and the food consumed was found in a study by Skinner *et al.* (1997). The least favourite foods were green beans, broccoli, carrots and peas. These foods were reported to be eaten daily or nearly daily, which indicates that the mothers did not let the child dictate what food was offered (Skinner *et al.* 1997).

Cow's milk

The Euro Growth study (Freeman *et al.* 2000) concluded that the use of cow's milk as the main drink before the age of 12 months was still common in certain European Centres. The National Food Administration in Sweden (Livsmedelsverket) is responsible for information concerning food intake. Since 2003 the recommendation in Sweden is to delay the introduction of cow's milk until 10–12 months of age (Axelsson *et al.* 1999).

Several studies have shown a negative correlation between cow's milk and iron status (Michaelsen *et al.* 1995, Freeman *et al.* 1998, Thane *et al.* 2000, Male *et al.* 2001, Karr *et al.* 2001, Thorsdottir *et al.* 2003, Gunnarsson *et al.* 2004, Nguyen *et al.* 2004). The negative aspects of cow's milk are low iron content with low bioavailability, high protein content (Michaelsen 2000), the high calcium content in

the cow's milk (Hallberg *et al.* 1992) and increased intestinal blood loss (Ziegler *et al.* 1990). Thorsdottir *et al.* (2003) concluded that a daily milk intake above 500 g/day among one-year-old children should be avoided and this recommendation should also include children up to the age of two years (Gunnarsson *et al.* 2004, Soh *et al.* 2004.). A daily cow's milk intake >600 ml influences iron status negatively and increases the risk of iron depletion (Karr *et al.* 2001, Nguyen *et al.* 2004). Kwiatkowski *et al.* (1999) found that 2-year-old children with severe anaemia (Hb <60 g/L) had a mean intake of cow's milk exceeding 0.95 litres. However, in the study by Persson *et al.* (1998) no correlation between iron status and milk intake among twelve-month-old infants was found.

The different amount of calcium in the diet could clarify the differences in bioavailability in milk according to a study by Hallberg *et al.* (1992). The study by Grinder-Pederson *et al.* (2004) showed no decrease in non-haeme iron absorption due to different amount of calcium in the whole diet. Yeung & Zlotkin (2000) concluded that cow's milk after six months of age did not increase ID if iron-fortified complementary foods were given, but Briefel *et al.* (2004 b) suggested delaying the introduction of cow's milk until the age of one year.

Content of iron in the child's diet

The iron fortification of wheat in Sweden ceased in 1994–95 due to possible negative effects of iron overload among iron-sufficient individuals. This led to a significant increase in iron deficiency among teenage girls (Hallberg & Hulthén 2002). An unfortified diet to infants does not contain enough iron to cover the requirements (Hallberg 2004). This means that the intake of dietary iron may not cover the physiological iron requirements (Hallberg 2001, Fomon *et al.* 2005). The iron intake decreased from 96% of the recommended level at 12 months of age to 76% at 18 months according to a study by Picciano *et al.* (2000). One way to cover the iron need when complementary food is introduced is to give iron-fortified foods or supplement.

Not only the type of iron and the amount in the child's diet is important (Dallman *et al.* 1980 Olivares *et al.* 1999) but also the bioavailability of the whole diet (Hultén *et al.* 1995). Most dietary iron, approximately 90%, is non-haeme iron (i.e. cereals, fruit, and vegetables). The absorption is dependent upon the individual's iron status and the absorption is higher in an iron-deficient person than in an iron-sufficient one. Furthermore, it depends on both inhibitors and enhancers (Hallberg 2001). The most important inhibitors for non-haeme absorption are calcium, protein and phytate. Enhancers of non-haeme are ascorbic acid (AA) and haeme iron i.e. protein from animal (Fomon 2001). Hallberg *et al.* (2003) showed that meat in combination with AA increases the absorption of iron by 85%. The haeme absorption is less likely to be influenced by inhibitors and enhancers and there is only one inhibitor, calcium, and one enhancer, meat (Dallman *et al.* 1980). Using iron pots compared to

aluminium pots for cooking lowered rates of anaemia and improved growth among children (Adish *et al.* 1999).

In a study by Skinner *et al.* (1997) the most consumed food for children aged 2 to 24 months was cereals. It is the phytate content in the bread that inhibits the iron absorption (Brune *et al.* 1992). In a study by Lind *et al.* (2003) phytate-reduced porridge had no effect on iron status but haemoglobin was significantly higher and the prevalence of anaemia was lower in the group receiving phytate-reduced porridge. Iron-fortified breakfast cereals improved iron status among one-year-old children (Thorsdottir *et al.* 2003). One-year-old children who drank whole cow's milk and ate iron-fortified cereals had an increased risk of developing iron deficiency probably related to poor bioavailability of the iron in the cereal (Fuchs *et al.* 1993). The study by Persson *et al.* (1998) concluded that a high intake of cereals increased the risk of iron depletion due to the limitation of the bioavailability in the iron.

A positive correlation between iron status and meat has been found in several studies (Michaelsen *et al.* 1995, Requejo *et al.* 1999, Thane *et al.* 2000 Nguyen *et al.* 2004). The study by Haschke *et al.* (1988) concluded that consumption of commercially prepared Fe-fortified complementary food with meat protected term infants from ID even if iron intake was below the recommended level.

Adding meat to the complementary food has a positive effect on iron absorption (Hallberg *et al.* 2003). Fagerli *et al.* (1996) compared Norwegian children who had a high intake of dark bread and meat with immigrant children who ate more rice and vegetables. None of the Norwegian children was found to have iron-depleted stores while 14% of the immigrant children had depleted iron stores. Meat intake can prevent a decrease in Hb during infancy but had no effect on S-ferritin or TfR (Engelman *et al.* 1998). On the other hand, the study by Lind *et al.* (2004) found that a high iron intake was positively correlated with Hb during infancy. Iron intake between 12 and 18 months showed a positive correlation with S-ferritin as well (*ibid.*). Meat should therefore be included in one-year-old children's diet in order to improve their iron status (Thorsdottir *et al.* 2003). However, Skinner *et al.* (1997) reported that less than half of twelve-month-old children were consuming meat.

Despite the many programmes that use fortified complementary foods, data are scarce on the actual amount consumed. Hotz & Gibson (2001) concluded that an increased total intake and better bioavailability would improve the diet. On the other hand, since not all food offered is consumed, the quality, rather than the quantity, is the key aspect of complementary food (Lutter & Riviera 2003).

Factors influencing food intake

Feeding a child is more than just the physiological provision of food. The best single indicator of adequate intake is an infant's appetite. A breastfed child can self-regulate its total energy intake when other foods are introduced (Cohen *et al.* 1994), and feeding depends on the amount of food offered, the frequency with which it is

offered and the responsiveness of the caregivers (Pelto & Freake 2003). Both parents are responsible for the composition of the food offered to the child, but most studies refer to the mothers. The mother's perception of her role as a mother and her competence were found to reflect her confidence in her maternal behaviour and depended less on previous experience (Mercer & Ferketich 1995). Pelto (2000) highlighted issues such as (i) interactive feeding, (ii) the child's food preferences, (iii) feeding in response in order to improve complementary feeding practices. Engle & Zeitlin (1996) suggested that active feeding might be used to compensate for the child's lack of interest in food, since parents feel guilty and responsible if the child leaves the table without having eaten (Livingstone 1997).

Hörnell *et al.* (2001) concluded that both parents and professionals must be aware that accustoming a child to solid foods is a process which requires a great deal of time, and parents have varying degrees of tolerance for dealing with fussiness in their children (Hobbie *et al.* 2000). Maternal education is found to have an influence on the child's diet (Wachs *et al.* 2005) but not in reducing anaemia (Jain *et al.* 2000). If the mother is highly educated the chance of the child being fed according to recommendations is higher (Dubois & Girard 2003). On the other hand, a study by Amsel *et al.* (2002) showed low compliance by parents in giving iron-containing medication to their infants mainly among parents from high socioeconomic groups. Dietary health education increased the mother's knowledge but changed the children's diet only modestly (Ilett & Freeman 2004). Mothers' practical knowledge may therefore be more important than the maternal education (Appoh & Krekling 2005).

During the child's first years it learns an extensive amount about food and eating, and this learning develops in the family context (Birch & Krahnstoever 2001). The mother's sensitivity and responsiveness contributed to a positive behaviour (Pridham *et al.* 2001). Gupta *et al.* (1999) found no differences in nutritional knowledge between mothers of children with low iron status and mothers whose children had normal iron status. On the other hand, there was an association between the mother's perception of feeding difficulties and low iron status. Some conclusions from a study by Briefel *et al.* (2004 a) were that parents or caregivers should be educated (i) to offer a variety of nutrients, (ii) to give iron-rich food, and (iii) to honour the child's hunger.

Since children eat what they like it is important to understand how their preferences arise (Cooke 2004). In a study by Koivisto & Sjöden (1996) the result showed that general neophobia decreased with increasing age and that the higher reports of neophobia, the fewer uncommon foods had been served in the family. On the other hand, the study by Carruth *et al.* (2000) showed that the children's neophobic behaviour did not improve with maturity and that the mother's perception of their children's picky-eater status was inconsistent over time.

Child Health Service

In Sweden, the Child Health Service (CHS) has a child health promotion programme intended to identify risk factors for the child's health (Sundelin & Håkansson 2000). One risk factor is a deviation of growth, which could be the first sign of medical, socio-emotional or nutritional problems (van't Hof *et al.* 2000). The CHS reaches nearly all families and issues regarding nutrition are an important part of their work. According to parents' perceptions, feeding difficulties are one of their most common problems, and this has been almost consistent over time. The parents' willingness to use CHS was found to be partly related to what degree the nurses focused on paediatric services (Magnusson *et al.* 1995). Most regions in Sweden have guidelines for recommendations regarding timing of introduction and the type of complementary foods (Hedberg-Nyqvist & Kylberg 2000). However, according to Hauck & Irurita (2002) findings indicate that there are as many different opinions regarding feeding as there are people to express them, and mothers expected unconditional support from the nurses at CHS in their decisions.

Andrews (1999) found a discrepancy between an approach from CHS as "non-expert" with the ambition to empower the parents and the expressed needs of the families. The nurses were supposed to be both traditional experts and also to be able to empower the parents. In a study by Baggens (2001) the visit to the CHS was audio-taped and the conclusion was that it was the nurse who initiated most of the topics discussed according to the official child health promotion programme. The nurse decided the timing and the nature of the advice given (Baggens 2002). This resulted in standard solutions being given. It is of great importance that the approach of the professionals at the CHS integrates both biological and social sciences (Pelto & Freake 2003). Important quality indicators include kind treatment, competence, time support and an individual perspective (Jansson *et al.* 1998) but not all support is experienced as positive (Hauck & Irurita 2002, Arborelius & Bremberg 2003). In a study by Zaffani *et al.* (2005) there was a discrepancy between the professional at the CHS and the mothers regarding the need for support. The professionals reported that 2/3 of the mothers were anxious and required therapy. Only 9.7% of the mothers said that they required therapy, mainly the younger mothers with lower education.

Intervention studies with dietary education have shown a reduction of ID (James *et al.* 1989) and improved complementary feeding due to increased energy and iron intake (Hotz & Gibson 2005). S-ferritin was significantly higher (Kapur *et al.* 2003) and maternal recall of recommendation was higher after intervention (Santos *et al.* 2001). Bogen *et al.* (2000) concluded that a use of dietary history as a screening for IDA was not effective, but diet history works well as a method to assess dietary intake among 15- to 16-year-old girls (Sjöberg & Hultén 2004). Effective combating of iron deficiency suggests that implementation should be in balance with research and community involvement (Yip 2002). A summary by Trowbridge & Martorell (2002)

elucidated the importance of utilizing multiple and integrated strategies to prevent iron deficiency. This includes investigating the knowledge about infant feeding among professionals (Williams & Pinnington 2003). It is also important to provide nutrition education for parents, to improve nutritional guidelines in order to improve children's nutrition and health (Freeman *et al.* 2000).

Nutrition information

Hobbie *et al.* (2000) found that parents needed more information about basic nutrition. Evaluation of nutritional knowledge and feeding practices showed that very high-risk populations may not benefit from nutritional programmes (Venkateswaran *et al.* 1998). Jain *et al.* (2000) showed that exclusive breastfeeding to four months and early weaning (i.e. <6 months) had a positive impact on the prevalence of anaemia. Late weaning correlated positively to mothers perception of the child being "little and weak" (Simondon *et al.* 2001). The Avon Longitudinal Study of Parents and Children (ALSPAC) study (Phillips 2004) showed that late introduction of "chewy food" was associated with feeding difficulties later on.

Not all parents follow the paediatric nutrition recommendations, suggesting that nutritional guidance should be developed (Picciano *et al.* 2000). Williams & Pinnington (2003) interviewed nurses concerning their knowledge about nutritional recommendations and concluded that further education was required. Nutritionally trained physicians were more likely to engage in nutritional counselling and to give more extensive advice than physicians in a control group (Pelto *et al.* 2004). They also used communication skills to improve the information and assure themselves that the mother understood, which led to a higher rate of recalling information about feeding practices and food recommendations (*ibid.*). Briefel *et al.* (2004 b) conclude that some parents and caregivers require guidance during transition to feed the child when it is hungry without forcing or bribing. Parental strategies could be, for instance, "eat your beans and you will get some ice cream afterwards" (Cooke 2004). Instead parents should try to enhance their child to eat with love, patience and humour (Penny *et al.* 2005). Nutritional advice aims both to emphasize iron-rich food and also to optimize iron status with enhancers and to avoid inhibitors (Gibson 1999). Faber & Benade (1999) stress the importance of high-quality food rather than quantity. Childs *et al.* (1997) found no reduction in anaemia using a targeted nutritional programme, but Sethi *et al.* (2003) found that nutritional education can bring improvements concerning both awareness and infant feeding practices. Some mothers may need help to notice and to respond to their infants' needs and preferences (Pridham *et al.* 2001) and nurse's efforts to enhance a model of feeding may help mothers to feed with more positive behaviour.

The efforts that have been made have had limited effect (Trowbridge & Martorell 2002) and the lack of success in preventing ID may be due to insufficient intervention programmes and ineffective communication tools (Yip 2002). In future

endeavours it will be important to integrate social and biological science (Pelto 2000, Pelto & Freake 2003). Since ID increases the risk of developmental delays, it is important to understand why there still are many children whose diets are insufficient in iron content (Wachs *et al.* 2005). Better tactics may be the key to eradication of iron deficiency in early childhood (Cohen 1999). In Sweden there is a lack of knowledge regarding the prevalence of ID among children in early childhood and possible factors influencing ID. To be able to prevent ID, these issues need to be further elucidated.

AIMS

The overall aim was to describe the prevalence of iron deficiency and factors influencing iron nutrition among otherwise healthy children.

Specific aims:

- to describe iron status among 2½-year-old children in Sweden in relation to intake of cow's milk and follow-on formula.
- to describe iron status, iron intake and possible factors influencing iron status and iron intake among one-year-old children.
- to elucidate mothers experiences of feeding situations.

MATERIALS AND METHODS

Design

This thesis includes two cross-sectional studies (I+II), the first part of a prospective study (III) and a qualitative study (IV).

Setting

The studies were performed in Malmö, which is a city in the south of Sweden with approximately 270,000 inhabitants. A total of 166 different countries are represented in the population (Malmö City 2006). There are 19 Child Health Centres (CHCs) which provide health care free of charge to all families. In 1995 (I+II) 40% of the children in Malmö were defined as immigrants according to the definition born abroad or with at least one parent born abroad (SCB 1995). Thirty-two percent of the children were immigrants according to the definition used during 2003, i.e. born abroad or both parents born abroad (SCB 2003) (III+V).

Participants

Children and their parents were recruited from the CHS. Since not all of the total population of 2½-year-old children (n=3004) visited the CHS for check-up during 1995, this left 1287 families answering the invitation (I+II). This invitation also included screening for celiac disease, which was given priority concerning blood sampling. Finally 367 children participated in the screening for iron deficiency (I) and 263 children in the study concerning TfR (II).

The inclusion criteria were: (i) no infection at the time of blood sampling or any clinical sign of infection a week before; (ii) CRP <10 mg/L; (iii) no chronic disease that could affect iron status (I-III). Furthermore the inclusion criteria among one-year-old children (III) were gestational age ≥ 37 w, birth weight > 2500 g. The criteria for participation (IV) were that the parents spoke Swedish and that the family had a healthy one-year-old child without any known feeding difficulties. Eighteen mothers who could understand and speak Swedish agreed to participate. Most parents came from Sweden (n=25) but eleven parents represented eight different countries such as Poland, Croatia, Congo, Afghanistan, Peru, Iraq, Denmark and Bosnia (IV).

Procedure

During 1995 the nurses at the CHS were asked to invite families who came for a routine control with their 2½-year-old child to participate in a screening for iron deficiency (I+II). Both oral and written information about the purpose and procedure of the study was given to the parents. The parents received information about the results of the blood samples. When iron deficiency or iron deficiency anaemia was diagnosed, iron treatment with ferrous succinate, 3.7 mg Fe²⁺ /ml in

doses of 5 ml twice a day was given. A control blood sample was taken following treatment.

The researcher randomly selected 500 healthy one-year-old children (n=3182) and their parents from the CHC (III). The nurses were asked to administer an information letter about the study to the parents. The information was translated into four different languages: Somali, English, Arabic and Albanian. Among those who answered (n=227), 115 wanted to be contacted for further information. Twenty-five of the contacted parents claimed that they had no time to record the child's total food intake, which resulted in 90 participating children and their parents. All contacted parents spoke and understood Swedish. The nurses at three different CHS centres, serving a total of 11 districts, were asked to invite parents with different age, educational level, ethnicity and number of children in order to receive a variety in the sample to participants (IV).

Definitions

Anaemia was defined as Hb levels below 110 g/L (WHO 2001) (I+II) or Hb levels below 100 g/L (Dommelöf *et al.* 2002) (III). Children with S-ferritin <12 µg/L were considered iron-depleted (WHO 2001) (I-III). Iron deficiency was defined either as S-ferritin <12 µg/L in combination with one abnormal test for either MCV (≤ 75 fL), S-Fe (<10 µmol/L) or transferrin saturation (<10%), or as an S-ferritin concentration in the range of 12–19 µg/L in combination with two abnormal tests (I+II). Iron deficiency anaemia was defined as iron deficiency in combination with Hb <110 g/L. (Fomon 1993, Oski 1993). Iron deficiency among one-year-old children was defined as the presence of at least two abnormal values (Looker *et al.* 1997) of either S-ferritin ≤ 12 µg/L, MCV ≤ 72 fL or TfR >2.5 mg/L (III). Iron deficiency anaemia was defined as Hb concentrations ≤ 100 g/L (Dommelöf *et al.* 2002) in combination with iron deficiency. Immigrant children were defined as born abroad or with one parent born abroad (Official Statistics 1997) or born abroad or with both parents born abroad (Official Statistics 2003).

Data collection

Blood sampling

Capillary blood samples were obtained from 2½-year-old children (I+II) and one-year-old children (III) at a paediatric laboratory at the University Hospital Malmö. Analyses of haemoglobin (Hb), serum ferritin (S-ferritin), transferrin receptor (TfR) were conducted as a primary screening (I+II). If Hb was below 110 g/L and/or S-ferritin was below 20 µg/L, the child was invited to take further tests as a second screening. Next blood samples were taken before 10.00 pm for analysis of serum iron (S-Fe), total binding iron capacity (TIBC), mean corpuscular volume (MCV), mean cell haemoglobin concentration (MCHC). Haematological parameters were measured on a Coulter STKS cell counter (Coulter Instruments, Inc., Fullerton, CA,

USA) The overall precision of the methods used reported as CV%: B-haemoglobin 3%, B-MCV 1% and MCHC 2% at relevant clinical levels. S-ferritin was analysed using a Technicon Immuno I instrument calibrated with Technicon SET point calibrator, with an imprecision of 7% at 73 pmol/L and 6% at 325 pmol/L. Serum was separated immediately and frozen at -20°C . TfR was measured with an enzyme-linked immunosorbent assay (Ramco Laboratories, Houston, TX, USA). The intra-assay coefficients of variation CVs were 5–7% at normal or high concentrations and 13–16% at low concentrations. The inter-assay CVs were 6–9% at normal or high concentrations and 13–16% at low concentrations. S-Fe and TIBC were analysed on a Technicon DAX 48 autoanalyser (Technicon Instruments, Tarrytown, NY, USA). Total imprecision was 5% for S-Fe and 7% for TIBC at 33 $\mu\text{mol/L}$ or 5% at 44 $\mu\text{mol/L}$.

Blood for analyse of Hb, S-ferritin, and TfR was collected (III). Haematological parameters were measured on a Coulter Gens and LH 750 cell counter (Coulter Instruments, Inc., Fullerton, CA, USA). The overall precision of the methods used reported as CV%: B-haemoglobin 5% at 60 g/L and 4% at 12 g/L and B-MCV as 2%. S-ferritin was analysed using Dxl 800, with an imprecision of 10% at 20–200 $\mu\text{g/L}$, with an imprecision of 10% at 20–200 $\mu\text{g/L}$ calibrated with Beckman Ferritin Calibrators. TfR was nephelometrically determined by N Latex reagent sets (Dade Behring) The total CV was 2.3% at 0.69 mg/L and 3.5% at 1.62 mg/L (van den Bosch *et al* 2001). Blood from all children (I-III) for analysis of CRP was obtained in order to exclude an infection, which may cause falsely high S-ferritin values. If a low Hb in combination with a low value of MCV was found thalassaemia was excluded.

Food records

The intake of cow's milk and follow-on formula was obtained from the child's parents. The nurse at the CHS asked the parent to estimate the child's daily intake at inclusion (I+II). The parents received detailed instructions, both verbally and in writing, on how to record the child's intake and the child's total intake was recorded for 5 days by the parents (III). The instructions were to specify food in weight, to use household measurements, to describe the size of meat or bread (cm x cm), the amount of fat in the butter or cheese (%) and the amount of liquids (ml). The records were sent to a dietician who read the records and had the possibility to contact the parents if supplementary information was required. Breastfeeding frequencies were registered.

Questionnaires

A self-administrated questionnaire containing 33 questions was sent to the parents along with a postage-paid response envelope at inclusion in the study (III). Sixteen questions came from a questionnaire used monthly among 8-month- and 4-year-old children in Malmö and administered by the CHS. These questions concerned

demographical data such as parental education, ethnicity, smoking habits, socioeconomics and the child's health. Seventeen questions were food-related and constructed for this study. These questions covered breastfeeding, complementary foods, parental experiences of feeding habits/situations and food information from the nurse at the CHS. The food-related questions were pilot-tested among 14 randomly chosen parents at a CHC for face validity. A few linguistic changes were made after this. The questions were open-ended (n=11) or given fixed choices (n=22) followed by the possibility to add further information.

Interviews

Interviews were carried out in the families' homes except in one case where the interview took place in a special room at the CHS according to the mother's wish (IV). All interviews were performed by the same researcher, audio-taped and then transcribed verbatim by the same person. The mothers were asked to narrate their experiences of feeding situations. An interview guide with open-ended questions was used in order to cover some areas in each interview. The questions concerned the child's personality, experiences concerning breastfeeding, the weaning period and feeding situations during the first year and at present. Specific questions were asked, for example: "Tell me about your experiences concerning feeding your child during the first year?" "Can you describe a feeding situation from the child's first year?" "How do you experience feeding your child now?" "Can you describe a feeding situation from last week?" In addition, the mothers were asked to describe the support they received from friends, relatives and the CHS nurse. Subsequent questions were only asked to clarify statements from the mothers.

ANALYSIS

Statistical analyses

Blood samples were obtained for evaluation of iron status in order to statistically compare iron status with dietary intake and the results from the questionnaire. The dietary intake was transferred into the computer for analysis of energy, protein, phytate, vitamin C, carbohydrate, iron and calcium (III). Dietary data were calculated in Dietist for Windows, which uses the food composition tables of the Swedish National Food Administration. The data were complemented with recipes from the parents or the manufactures. The results were transferred into SPSS for further calculations. The answers from the questionnaire were coded into numbers in order to make statistical calculations (III). The distribution of milk intake was skewed and was therefore subjected to logarithmic transformation (I+II+III). S-ferritin was skewed (I+II+III) and was logarithmic transformed (II+III) but since there were more than 30 values in each group in paper I logarithmic transformation was not performed.

Results are expressed as means, standard deviation or confidence interval. Groups were compared by paired t-test (I+II) unpaired t-test (I+II) and ANOVA (I-III) ² or Fisher's exact test (I+II). Fisher PLSD was used as a post-hoc test in ANOVA. Spearman's rank correlation was used to test correlation between variables. Results were considered to be statistically significant if p-values were < 0.05. Stat-View, SAS Inc., Cary, NC, USA (I+II) and SPSS for Windows 12.0.1 Inc, Chicago IL (III) were used for statistical analyses.

Qualitative analysis

The text was analysed using qualitative content analysis at both manifest and latent levels in order to discover possible similarities and differences (Neumann 1997) (IV). The manifest content analyses focus on the surface structure of the text and what was actually said. Latent content analysis focuses on the deep structure of the texts. This approach is in agreement with Neumann (1997), who discusses a systematic procedure to produce a quantitative description of the content of the text. Latent coding looks for the underlying implicit meaning in the text. Initially, each interview was read as a whole to acquire a naive understanding of the text and to obtain a holistic view. Secondly the text was read in order to look for core meanings. Thirdly, a more structural analysis was conducted where meaning units reflecting the mother's experiences were identified. The different meaning units were then categorized compared and sorted by content. After this, all the interviews were reread in order to check that the categorizations suited the entire text. Finally, the categories were checked and discussed by all authors until agreement was achieved.

Preunderstanding

A researcher must be aware of how the preunderstanding may exert an influence in a qualitative (IV) study. The researcher's preunderstanding is a part of the interpretative process and can be used as a guiding tool. It is neither possible nor desirable to neglect the preunderstanding; instead can it be useful in approaching the parents and their experiences (Dahlberg *et al.* 2001). To avoid the preunderstanding influencing the study in a biased way, the interviewer reflected upon her experiences as a nurse at a CHS and wrote the reflections down in order to make them clear. The co-authors have extensive experiences of work and research with children. The authors' preunderstanding was reflected upon throughout the analysis in order to avoid bias in the analysis.

Table 1 Overview of papers I–IV

Paper	Aim	Subjects	Design	Findings
I	To describe the prevalence of ID or IDA among 2½-year-old children in relation to intake of cow's milk and follow-on formula.	367 children	Descriptive and cross-sectional	10% had ID or IDA. Children with ID had higher intake of cow's milk and fewer consumed follow-on formula.
II	To compare TfR with other iron status parameters, to measure TfR before and after treatment and to correlate TfR with intake of cow's milk and follow-on formula	263 children	Descriptive and cross-sectional	Differences in TfR/log.ferritin among those with a cow's milk intake > 500 ml and those ≤ 500 ml. Lower TfR was found after treatment.
III	To describe possible factors influencing iron status and iron intake among 12-month-old children	90 children	The first part of a prospective longitudinal study	Children of mothers with an education ≤ 9 years had lower iron intake and 27% of the non-breastfed children had an iron intake below recommendations.
IV	To describe parents' experiences of feeding situations	18 mothers	Qualitative	Some mothers expressed a need to control the child's food intake and established rules for the child's feeding, and some expressed flexibility and trusted their child's ability to regulate its food intake.

ETHICAL CONSIDERATION

Possible gains and potential pain or discomfort of the study must be considered carefully in all research, but specifically in research when children are involved. Young children are not able to give informed consent and a proxy decision maker must determine for them. For young children parents usually make the decision. (Beauchamp & Childress).

This thesis included blood tests in one-year-old and 2½-year-old children. The necessity of blood tests and the value gained from the results must be taken into serious consideration. Using results from studies on adults as an alternative is not adequate for the growing child. Considerations concerning the blood sampling procedure were undertaken during the planning of the studies. A blood sample taken from the finger causes more or less pain and venous blood sampling could be an alternative. A venous blood sample requires local anaesthetics and pain can thereby be reduced. On the other hand the child has to co-operate and this can be difficult to obtain when children are aged 1–2½ years. Furthermore, venous blood sampling is not always successful and more than one try may be necessary. In order to minimize the child's discomfort the child was sitting in the lap of the parent or caregiver to achieve optimal comfort. All blood samples were performed at a laboratory where the staff had long experience of obtaining blood samples from children. The environment at the laboratory was adjusted to children and included toys and music boxes, making it possible to distract the child.

All parents of participating children received both oral and written information about the purpose and procedures of the studies, and informed consent was obtained from the parents. The parents were informed that there were no predictable risks to their child but that the blood sampling may be associated with discomfort (I-III). Information was given about the benefit to the individual child if iron deficiency was discovered and treatment given. Children undergoing blood tests were given age-specific oral information about the procedure before the blood test. The participants had the possibility to contact the researcher at any time and a possibility to get medical advice if needed (I-III). The participants were not in any way dependent on the researcher (IV). The importance of being sensitive and emphasizing the right to decline to answer was kept in mind. Confidentiality was assured by a coding system before data were transferred to the computer for analysis (I-IV), and personal identification and interview transcripts were kept separately (IV) The studies were approved by the Ethics Committee of the Medical Faculty, Lund University: LU 223–94 (I+II) and LU 226–02 (III+IV).

RESULTS

One child with thalassaemia was found (I+II) and excluded from the study. In the longitudinal study (III) one child with thalassaemia was found and the child's blood samples were excluded from the analyses. Thirty-two percent of the children (I+II) were defined as immigrants (SCB 1997) and 15% in the longitudinal study (III) were classified as immigrants (SCB 2003). Participating parents came from 25 (III) and 8 (IV) different countries. Sixty percent of the children were firstborn and all except one child lived with both parents (III).

Iron status

The mean concentrations (\pm SD) of Hb and S-ferritin in all children were 122 g/L (\pm 8.0) and 26.6 μ g/L (\pm 14.3) respectively (I). Thirty-seven children had S-ferritin <12 μ g/L. The children with S-ferritin <12 μ g/L had significantly lower values of Hb, S-Fe and MCV and higher values for TIBC than those with S-ferritin concentrations \geq 12 μ g/L. Among the 367 children there were 111 children qualifying for the second screening (Hb <110 g/L and/or S-ferritin <20 μ g/L). Children with Hb \geq 110 g/L had significantly higher values of S-Fe and MCV than those with Hb <110 g/L. In all, 10% of the children had iron deficiency (n=35) and iron deficiency anaemia (n=25) and received treatment (I). There were significantly higher values for Hb, S-ferritin, MCV, S-Fe and lower concentrations of TIBC after iron treatment compared to the concentrations before treatment.

TfR was obtained from 263 children (II) and the mean concentration was 6.9 mg/L (SD 1.6). A cut-off value of <8.5 mg/L was chosen in accordance with WHO recommendations for adults (1994). The results showed that 14% of the children had elevated levels of TfR, indicating a need for iron in the cell. There was a negative correlation between TfR and MCV ($p=0.0007$) and the children with MCV \leq 75 fL had significantly higher TfR concentrations ($p=0.01$). Significantly higher values of TfR/log.ferritin were found in children with MCV \leq 75 fL than those with MCV >75 fL ($p<0.0001$). The children with TfR concentrations <8.5 mg/L had significantly higher values for Hb ($p=0.01$) and MCV ($p=0.005$) than those with high concentrations (\geq 8.5 mg/L) of TfR. Blood samples before and after treatment were obtained from eight children. The concentration of TfR after treatment were significantly lower than values before treatment ($p=0.001$). The TfR/log.ferritin ratio was also lower after treatment ($p=0.003$).

In the first part of the prospective longitudinal study (III), 10% (n=9) of the children were iron-depleted with an S-ferritin <12 μ g/L. Low values of MCV were found among 4.6% (n=4) of the children. Two children had iron deficiency, and received iron treatment. Blood samples were taken after three months of iron treatment. The values of Hb, MCV and S-ferritin were higher and TfR was lower after treatment. Eleven percent of the children (n=10) (III) had high TfR concentrations (>2.5 mg/L). There was a significant negative correlation between

TfR and MCV ($p < 0.0001$). No other correlation between other iron status parameters was found.

Dietary intake

Information about daily intake of cow's milk and follow-on formula was obtained from 90% (332/367) (I) and 79% (209/263) (II) and total dietary intake from 91% of the children (82/90) (III).

Breast milk

All children received breast milk initially and 8.8% received it in combination with infant formula from birth (III). The mean exclusive breastfeeding period was 3.4 months (SD 1.8). There were no significant differences concerning the length of the exclusive breastfeeding period between mothers with >9 years of education and those with ≤ 9 years. Eighteen children (19.6%) were partially breastfed at 12 months (III). Breastfeeding frequencies were obtained from 83.3% of these (15/18) and the mean frequencies were reported to be three times per day. Among the children who were partially breastfed at 12 months the mean iron intake from complementary foods was significantly lower than among those who did not receive breast milk ($p = 0.003$). Six mothers were still breastfeeding at the time of the interview (IV), and among the mothers who had stopped breastfeeding ($n = 12$) the partial breastfeeding period was between one month and 10 months (median six months).

Iron intake

The mean intake of iron (III) was 9.0 mg (SD 2.5). A total of 30.4% of the children had an iron intake below the recommended level of 8 mg/day (NNR 2004). Follow-on formula and iron-fortified porridge contributed 64% of the total iron intake (III).

Cow's milk

In the group of 2½-year-old children (I) 86% received cow's milk to drink and the mean intake was 325 ml (SD 210 ml). Among the one-year-old children (III) 59% received cow's milk to drink and the mean intake was 79 ml (SD 75). There was a negative correlation between cow's milk and mean iron intake ($p = 0.021$) (III). No correlation between intakes of cow's milk and partial breastfeeding was found (III).

Follow-on formula

Most of the one-year-old children (86%) received follow-on formula (III). The mean intake was 370 ml (SD 154). Among those receiving follow-on formula at 12 months the mean intake of iron was significantly higher than among those not receiving follow-on formula ($p < 0.0001$). The children who were partially breastfed at 12 months had a significantly lower intake of follow-on formula than those who

were not breastfed ($p < 0.0001$). Nearly half of the 2½-year-old children (44%) received follow-on formula and the mean intake was 362 ml (SD 153).

Complementary food

The mean age at introduction of complementary food (III) was 4.5 months (SD 1.0) and four children had received complementary food before 4 months of age (III). Ninety-one percent of the children had received pureed vegetables as their first type of complementary food. The mean age at introduction of cow's milk and meat was 9.7 and 6.2 months respectively (SD 2.3; 1.5) (III). One mother had started weaning when the child was three months and the others had started when the child was between 4 and 6 months (IV).

Iron status in relation to dietary intake

There was a difference concerning milk intake whether the child was iron-sufficient or iron-deficient, with or without anaemia (257 ml vs. 382 ml, $p = 0.0024$) (I). There was also a negative correlation between the amount of cow's milk intake and S-ferritin and MCV ($p = 0.0052$ and $p = 0.028$ respectively). Children with S-ferritin levels $< 12 \mu\text{g/L}$ had significantly higher intake of cow's milk ($p < 0.0001$) as did children with $\text{MCV} \leq 75 \text{ fL}$, compared to those with S-ferritin $\geq 12 \mu\text{g/L}$ or $\text{MCV} > 75 \text{ fL}$ ($p < 0.0001$). Eleven percent of the iron-deficient children consumed follow-on formula compared to 43% of the iron-sufficient children ($p = 0.0002$) (I). A positive correlation was found between the amount of follow-on formula and S-ferritin and S-Fe ($p = 0.010$; $p = 0.009$ respectively). The children with a total iron intake below recommended 8 mg/day had significantly lower values of MCV than those with an iron intake above 8 mg/day ($p = 0.004$) (III). There were no significant difference in cow's milk intake among children with TfR values $<$ or $\geq 8.5 \text{ mg/L}$. (II). On the other hand, there was a significant difference in TfR/log.ferritin among the children with a cow's milk intake above 500 ml compared to those with an intake below 500 ml ($p = 0.003$).

No significant difference regarding the intake of follow-on formula between children with TfR $< 8.5 \text{ mg/L}$ and those with TfR $\geq 8.5 \text{ mg/L}$ was found (II). There was a positive correlation between iron intake and Hb and MCV ($p = 0.004$ and $p < 0.0001$ respectively) (III).

Iron status in relation to ethnicity

There was a significantly higher proportion of ID with or without IDA among the immigrant children than among the Swedish children, 18% vs. 6% ($p = 0.0005$) (I). Cow's milk intake among Swedish children was significantly lower ($p = 0.0006$) than among the immigrant children (248 vs. 331 ml). Swedish children with ID or IDA had an average cow's milk intake of 383 ml and immigrant children a mean intake of

528 ml. Among the iron-sufficient children there were 105 Swedish children and 26 immigrant children who consumed follow-on formula compared to 3 Swedish children, and no immigrant child among those who were iron-deficient (I). Forty-eight percent of the 2½-year-old Swedish children and 24% of the immigrant children consumed follow-on formula (I). The immigrant children drank significantly less follow-on formula and they had a significantly lower weight at 12 months ($p=0.01$) compared to the Swedish children ($p=0.02$) (III).

Iron status and influencing factors

The weight at 12 months correlated positively with Hb ($p=0.04$) but negatively with S-log-ferritin (III). The children whose parents reported feeding difficulties had significantly higher Hb than those whose parents perceived no feeding difficulties ($p=0.02$). Among the children with S-ferritin ≤ 12 $\mu\text{g/L}$, 50% of the parents had received information about iron-rich food. There was a significant difference concerning the children's TfR values as regards whether the parent recalled receiving information about iron-rich food or not ($p=0.04$) but no other differences regarding other iron status parameters or iron intake. The children whose mothers reported a short education (≤ 9 years) had significantly lower iron intake ($p=0.003$) and lower Hb ($p=0.04$) and lower MCV ($p=0.009$) than children with mothers who had education >9 years. There was a negative correlation between the child's total iron intake and the number of siblings in the family ($p=0.009$).

Parental experiences concerning feeding situations

Nearly half of the parents (47%) of one-year-old children (III) reported that they experienced problems during the breastfeeding period. The main reason for that were sore nipples or the mother's perception of not having enough breast milk. Ten percent of the parents expressed problems stopping breastfeeding, the two main reasons for that being the child's neophobia towards complementary foods or that the mother expressed a feeling of not being a "good mother". Twenty-five percent of the parents experienced problems concerning feeding situations when the child was 12 months old, and the reasons here were the child's bad appetite. The parents reported that the child had a poor appetite and they had to manipulate the child in order to make it eat.

The interviews (IV) resulted in narratives including both experiences concerning the one-year-old child ($n=18$) and their siblings ($n=14$). All mothers reported that food was an essential part of their lives and that they had main responsibility for food and feeding in the family. Several of them experienced difficulties in presenting a variety of foods and some even stated that they doubted their own ability to cook. Initially two main differences in experiences were found, positive and negative experiences. Most mothers said that if the child ate they had a positive feeling and when the child did not eat they were affected negatively. How they experienced their

child's feeding situations influenced to a greater or lesser extent the picture they had of themselves as a mother.

Two main categories were identified concerning the attitudes mothers had in feeding situations: a flexible attitude and a controlling attitude. Mothers who had a positive experience trusted their child's capacity to regulate the food intake. The mothers were sensitive to the child's signals in order to achieve mutual communication. Mothers who had a controlling attitude thought they alone was responsible for the child's food intake. One way of controlling what everyone ate was to supervise the food intake or to decide when the child was hungry based on the time by making a feeding schedule. They expressed difficulties in interpreting the child's signals and uncertainty about the child's ability to regulate the food intake. Some mothers related feeding difficulties to the child's being petulant. The mothers could use threats or rewards to manipulate the child during the feeding situations in order to increase the amount of food intake.

Parental experiences of Child Health Services

All the mothers claimed that they received a large number of opinions concerning food and feeding from many different people (IV). A problem for some mothers was that the opinions differed, while others thought getting different advice was beneficial as they then could choose the advice that suited them the best. Mothers with a flexible attitude thought that they received adequate support from the CHS nurse. However, they did not need much support from the nurse, as they did not think their child had any feeding difficulties. Mothers with a controlling attitude experienced inadequate support from the CHS nurse and they did not feel that they had received any useful advice. They felt that the nurse had not listened to them and did not take their worries seriously. Food information from the nurses at the CHS was recalled by 93.4% of the parents and 34% recalled receiving information about iron-rich food. Over 90% of the parents were more or less satisfied with the information (III).

DISCUSSION

Public health problems are multidimensional and require different designs in order to elucidate the complexity. Methodological issues must be discussed concerning validity and reliability. In quantitative studies internal validity refers to the design of the studies and the quality of the instruments. External validity concerns the extent to which the results can be generalized to other populations, settings or contexts (Lincoln & Guba 1985). Four questions in relation to trustworthiness in qualitative studies refer to how true the findings are, *credibility*; how applicable the findings are in other contexts, *transferability*; whether the findings would be consistent if the research is replicated, *consistency*; and whether the findings are neutral and

determined by the subjects in the research or are biased by the researcher, *conformability* (Lincoln & Guba 1985).

Discussion of methodology

Involving small children in research which includes more or less painful parts requires considerations both from the researcher and the parents. Oral and written information to the parents is important as well as to make every effort to facilitate for the child as much as possible. Blood sampling from 2½-year-old children was a part of a cross-sectional screening for celiac disease (I+II) and blood was collected from the one-year-old children in the first part of a prospective study (III). Perhaps the parents who chose to participate were worried about celiac disease or iron deficiency, which might have influenced the representativity of the study populations. Unfortunately, no data concerning the reason for participating are available. Demographical and nutritional data, besides cow's milk and follow-on formula, would have been preferable but were not obtained since this was not the primary aim. The participating children (I+II) were recruited from 17 out of 19 CHS, suggesting representativity, although there was some overrepresentation from districts with higher SES. The chance of being fed according to recommendations is higher if the families are from high socioeconomic areas (Dubois & Girard 2003), which indicates that the children would have decreased risk of iron deficiency (I+II). One can only speculate as to whether the prevalence of iron deficiency might have been higher if the study population had come from more low income areas.

A high proportion of the participating parents had a university education (III). The parents were randomly chosen with the ambition to include a representative sample but only 45% (227/500) answered, of whom 115 wanted to be contacted for more information. Among the parents who responded to the invitation 112 claimed that they did not want to be contacted and this choice was esteemed. After ethical considerations, no investigation of non-participants was undertaken. This raises the question whether the study population is representative of the whole population. Participating in a prospective study including blood samples and time-consuming elements collected prospectively might be the reason why only 90 out of 500 invited parents finally chose to participate. High maternal education among mothers who participate with their children in research is in line with other studies (Khan & Falck 2003, van't Hof 2000). Maternal education influences iron intake and to some extent also iron status (Male *et al.* 2001). If the study population had included a higher proportion of mothers with shorter education, the prevalence of ID might have been higher.

The group of participating children included fewer immigrants (I-III) than the whole population. Thirty-two percent of the 2½-year-old children (I+II) were defined as immigrants according to the definition used during 1995, compared to 40% in the whole population. In the study population of one-year-old children 15%

of the children were immigrants compared to 32% in the total population. Considering that immigrant children had a high intake of cow's milk (I+II) and a higher prevalence of iron deficiency, it would have been valuable to include more immigrant children. On the other hand, 27% of the parents were born abroad, representing 25 different countries, which makes the proportion of foreign-born parents satisfactory (III).

Bone marrow smears are the golden standard for evaluating iron status (Hallberg 2001) but they are not possible or ethically defensible to perform among children. Instead blood samples were obtained and multiple criteria used in the diagnosis (I-III) according to Looker *et al.* (1997). The inclusion criteria in the two populations (I+II and III) were that there was no known chronic disease that would affect iron status. Two children with thalassaemia minor were found accidentally (I-III) and further medical consultations were conducted. Furthermore, the birth weight (III) should be > 2500 g in order to exclude children with small iron stores from birth. Despite these criteria, 10% of the children were found to be iron-depleted (III) or iron-deficient (I+II). The prevalence concerning iron deficiency varies due to different criteria in the diagnosis, which makes comparison between different studies limited. The figures in these studies (I-III) would have been different if other criteria had been used, but no definite consensus regarding criteria exists. The levels of TfR have been shown to be a reliable test for detecting iron deficiency (Kohgo *et al.* 1987, Flowers *et al.* 1989, Skikne *et al.* 1990, Huebers *et al.* 1990, Punnonen *et al.* 1997, Feelders *et al.* 1999). Fourteen percent of the 2½-year-old children (II) and 11% of the one-year-old children (III) had high levels of TfR. Interestingly, it was not the same children (III) who had high levels of TfR and depleted iron stores, but this could be due to the fact that it might take several months to empty the stores. Since other studies have shown a relationship between ID and development (Idjradinata & Pollitt 1993, Stoltzfus *et al.* 2005), these children might have benefited in developmental outcome by participating in the study (I-III).

The questionnaire contained both validated questions (Khan & Falck 2003) and questions constructed for this study. It would have been preferable if all of the questions had been validated, but such questions were not available. Instead the food-related questions were pilot-tested among randomly selected parents at a CHC to validate the language and the relevance of the questions.

Being interviewed can be intrusive and requires special gentleness on the part of the interviewee (IV). The interviewee and the interviewed were unknown to each other and therefore not in any way dependent on one another. Both parents were invited but only mothers agreed to participate. The results might have been different if fathers had participated too. Since the mothers claimed they were responsible for the food in the family, it is not surprising that it was the mothers who chose to be interviewed. Furthermore it is possible that the participating mothers already had a special interest or special concern regarding food, and the result may have been

different if those interviewed had been another group of mothers. The mothers differed regarding age, education and numbers of children in order to enrich the data by ensuring rich variation in the interviews. The researchers' preunderstanding might influence the analyses in a biased way, but by writing earlier experience down and to reflect upon it throughout the study the researcher tried to minimize the risk (Dahlberg *et al.* 2001). All three researchers (IV) took part in the analysis to increase credibility. A qualitative study does not claim to generalize but to arrive at a better understanding.

Discussion of the findings

Adequate feeding of a child is of much concern to parents and requires special attention from the CHS (III+IV). The findings in this thesis show that iron deficiency exists during early childhood in Sweden (I-III). Ten percent of the one-year-old children were iron-depleted (III) and 10% in the population of 2½-year-old children were iron-deficient (I). This indicates that healthy growing children in Sweden have an increased risk of developmental delays (Hurtado *et al.* 1999) and a risk of long-term consequences even after 10 years (Lozoff *et al.* 2000).

As far as we know, no indications of iron depletion among the children were known to either parents or CHS before the blood samples were taken (I-III). Kwiatkowski *et al.* (1999) reported that 45% of the children with severe anaemia were found incidentally and pallor was only found among half of children with severe iron deficiency anaemia (Morad 1998). This raises the question how iron depletion can be detected by the CHS, and the challenge must be to find the mild and moderate cases of iron deficiency. Cohen (1999) suggests that further gains in the prevention of iron deficiency in infants and children should come from public health initiative rather than from improved technology.

The children with iron deficiency received iron treatment and all of them showed better iron status after treatment. An increased Hb value (Oski 1993) and improved iron status (Allen *et al.* 2000) is suggested to be evidence for iron deficiency. Whether or not the children's development improved after iron treatment was not investigated. There is no clear evidence that iron therapy has any beneficial effects on psychomotor development, which indicates that prevention by nutritional guidance must be a priority (Martins 2001).

All mothers of the one-year-old children reported that they started to breastfeed and the mean exclusive breastfeeding duration was 3.4 months (III). There were no differences regarding exclusive breastfeeding duration between mothers with different levels of education. The maternal education (Michaelsen *et al.* 1994, Dubois & Girard 2003) and maternal confidence (Blyth *et al.* 2002) have been reported as influencing factors for improved breastfeeding duration. Considering that many of the mothers had a university education, the exclusive breastfeeding period might have been expected to be longer (III). The interviewed mothers (IV) said that if they

succeeded in breastfeeding they felt like “a good mother”. This has also been described in other studies which conclude that the ability to breastfeed is a proof of womanliness (Bottorf 1990) and a demonstration of good mothering (Hauk & Iriruta 2002). Almost half of the parents (III) reported problems during the breastfeeding period, and many regions in Sweden provide breastfeeding classes for parents (Hedberg-Nyqvist & Kylberg 2000). It would have been interesting to know whether these mothers were offered any education regarding breastfeeding, but this has not been investigated.

Ten percent expressed difficulties stopping breastfeeding and mentioned the child’s neophobia (III). Neophobia may be consistent over time (Carruth *et al.* 2000) or decrease with age (Koivisto & Sjöden 1996). It is important that parents and professionals are aware that it takes time to accustom a child to solid foods (Hörnell *et al.* 2001) and parents differ in their tolerance of petulance in their children (Hobbie *et al.* 2000). It would have been interesting to know whether the mothers experienced adequate support from the CHS in the period when complementary foods were introduced, but this information is not available (III).

Almost all parents who answered the questionnaire were satisfied with the food information given by the CHS but only one third recalled receiving information about iron-rich food (III). There were significantly lower levels of TfR among the children whose parents recalled receiving information about iron-rich food, indicating that the information improved the child’s iron status. The mothers who experienced feeding difficulties reported a lack of support from the CHS (IV). This might be due to the fact that no feeding difficulties were known by the CHS. The study by Williams & Pinnington (2003) showed that nurses needed more education concerning food and feeding. If the nurses at CHS in the city where the study was performed (III) had been given the opportunity to attend education about iron deficiency and the potential consequences, more parents might have received information about iron-rich food.

Twenty-seven percent of the non-breastfed children had an iron intake below recommendations and they might be at increased risk of developing iron deficiency (III). A high proportion (86%) received follow-on formula and follow-on formula and iron-fortified porridge contributed 64% of the total iron intake among the children (III). This indicates that iron-fortified food is an important iron source, which is in line with other studies (Gill *et al.* 1997, Morley *et al.* 1997, Male *et al.* 2001, Soh *et al.* 2004). The unfortified diet often contains insufficient amount of iron to meet the child’s requirements (WHO 1998). The prevalence of IDA among children during in recent decades may be due to the increased use of iron-fortified formula and improved bioavailability of iron used to fortify infant food (Looker *et al.* 1997)

Milk intake among the one-year-old children (III) was relatively low. New recommendations to delay the introduction of cow’s milk until the age of 10–12

months (Axelsson *et al.* 1999) have probably contributed. The 2½-year-old children drank more cow's milk and there was a significant correlation between milk intake and iron deficiency (I). To our knowledge no other study in Sweden has described the correlation between cow's milk and ID in this age group, although several studies from other countries have (Male *et al.* 2001, Karr *et al.* 2001, Thorsdottir *et al.* 2003, Gunnarsson *et al.* 2004, Nguyen *et al.* 2004).

Mothers who experienced feeding difficulties and thought that their child was “fussy” reported a need to control by making up rules concerning feeding situations (IV). These mothers reported that the nurse at the CHS did not respond to the worries. Instead the nurse assured the mother that the child was growing satisfactorily, but this did not calm the mothers. The CHS had not registered any feeding problems, which might be the reason why no advice was given. The results from a qualitative interview can not be generalized to other contexts. Instead it can contribute to a better understanding regarding mother's experiences of feeding situations. Parents' perception of feeding difficulties is one of their most common problems (Magnusson *et al.* 1999) and mutual understanding between professionals at CHS is important (Zaffani *et al.* 2005). Health professionals can contribute to practical health education (Gilbert 1998) as prevention of iron deficiency is a superior approach to screening and treatment (Yip 1990). It is encouraging that the mother's nutritional knowledge may be more important than maternal education (Appoh & Krekling 2005). Protocol advice for iron deficiency could be a tool for health professionals and incorporated into the early programmes (Couper & Simmer 2001). Yet even if the nutritional and health intervention approach is multidimensional, one approach does not fit all (Pelto & Backstrand 2003). Knowledge about adequate nutrition during childhood (Hurtado *et al.* 1999) and the importance of meeting the high iron requirements in order to optimize development (Hallberg 2001) needs to be included in the prevention.

CONCLUSIONS

- Ten percent of the one-year-old children were iron-depleted and 10% of the 2½-year-old children had ID.
- Eleven percent of one-year-old children and 14% of 2½-year-old children had elevated levels of TfR, indicating an iron need.
- Intake of cow's milk was a negative factor influencing iron status among 2½-year-old children.
- The TfR/log ferritin ratio was higher among children with a cow's milk intake > 500 ml than in those with an intake < 500 ml.
- Follow-on formula improved iron stores.
- Iron intake among one third of one-year-old children was below recommendations.
- Follow-on formula was an important source of iron for growing children.
- Twenty-five percent of parents of one-year-old children reported problems concerning feeding situations.
- Mothers experienced different attitudes, flexible and controlling, in order to accomplish satisfying feeding situations.

POPULÄRVETENSKAPLIG SAMMANFATTNING

En god näringstillförsel är viktigt för att ett barn ska växa och utvecklas tillfredställande. De första 2-3 åren innebär en kraftig tillväxt och optimalt kostintag är därför extra viktigt under denna perioden. Barnets vikt tredubblas först året och längden ökar med 50 %. Hjärnan har en kraftig tillväxt de första 3 åren. Således är näringsbehoven relativt sett störst de första 3 åren.

Bröstmjolk är den optimala näringen de första sex månaderna. Därefter rekommenderas bröstmjolk i kombination med näringsriktig tilläggs-kost. Övergången från bröstmjolk till tilläggs-kost är en känslig period och risken att utveckla järnbrist är stor. Det är viktigt att föräldrar är informerade om att det kan kräva både kunskap, tid och tålamod att vänja ett barn vid annan kost än bröstmjolk. Ett friskt barn kan reglera sitt intag men sammansättningen av maten är föräldrarnas ansvar. Matvanor grundläggs under tidig barndom och präglar inställningen till mat även senare i livet.

De nordiska näringsrekommendationerna är vetenskapligt framtagna och om de följs kommer de allra flesta barn att täcka sina näringsbehov. Den oöverskådliga maten är ofta näringsmässigt otillräcklig för barn. Om tilläggs-kosten inte motsvarar näringsbehoven kan bristtillstånd uppstå och järnbrist är ett av de viktigaste nutritionella bristtillstånden. Ett flertal studier har visat ett samband mellan järnbrist och försenad mental och motorisk utveckling. Komjolk har i ett flertal studier visat sig vara en faktor som påverkar barns järnstatus negativt. Därför har nya rekommendationer utarbetats av en pediatrik expertgrupp som rekommenderar introduktion av komjolk först vid 10-12 månaders ålder.

Barnhälsovården har en viktig uppgift i att detektera riskfaktorer i barnens närmiljö för att optimera förutsättningarna för det växande barnet. Att förebygga nutritionella bristtillstånd bör prioriteras före att detektera järnbrist. Detta innebär bland annat att ge adekvat kostinformation, råd i samband med introduktion av ny mat och skapandet av rutiner kring matsituationerna. Mödrarna har oftast det största ansvaret för mat och uppfödning av det lilla barnet. Mödrarnas utbildning har betydelse för barnets intag.

Syftet med den första studien var att undersöka förekomst av järnbrist bland friska 2 ½ åringar i Malmö. Rekruteringen av barn och föräldrar till den två första delstudierna skedde via barnhälsovården i samband med 2 ½ års besöket. Sjuksköterskan inom barnhälsovården bad föräldrarna uppskatta barnets dagliga intag av komjolk och välling. Föräldrar fick kallelse till barnet för ett blodprov i fingret för att bestämma barnets järnstatus. Föräldrarna fick besked om blodproven via brev. Tio procent av barnen visade sig ha järnbrist och fick flytande järnmedicin i tre månader. Därefter togs ett nytt blodprov. Alla barnen hade förbättrat järnstatus efter behandlingen.

Vid jämförelse mellan blodprov och intag av komjolk visade det sig att det fanns ett samband mellan järnbrist och komjolk. De barn som hade järnbrist drack mer

mjölk än de barn som inte hade järnbrist. Nästan hälften av 2 ½ åringarna drack välling. Det fanns ett positivt samband mellan intag av välling och storleken på barnens järnförråd. Endast elva procent av barnen som hade järnbrist drack välling jämfört med 43 % av de barnen som inte hade järnbrist. Detta tyder på att välling kan förebygga uppkomsten av järnbrist.

Syftet med den andra delstudien var att beskriva koncentrationen av transferrin receptorer genom blodprov. Detta blodprov ger information om cellens behov av järn. Fjorton procent visade sig ha förhöjda koncentrationer av transferrin receptorer. De barn som drack mer än 500 ml komjölk hade högre koncentration av kvoten av transferrin receptorer/ferritin än de barn som drack mindre än 500 ml. Detta indikerar att ett högt intag av komjölk resulterar i en ökad risk för att utveckla hjärnbrist.

Dessa resultat ledde till nya frågor. Därför startades en studie som avsåg att beskriva barns järnstatus vid ett år, barns totala kostintag samt faktorer som kan påverka järnstatus och järnintag. Ett blodprov togs i fingret för att bestämma järnstatus. Föräldrarna skrev ner allt vad barnet åt under fem dagar Dessutom fyllde föräldrarna i ett frågeformulär med frågor som gällde föräldrarnas ålder, utbildning och födelseort samt frågor kring barnets uppfödning under första året. Resultaten visade att 10 % av barnen hade tömda järnförråd samt att två barn hade järnbrist och fick järnbehandling i tre månader. Tjugosju procent av de barn som inte fick bröstmjölk vid 12 månaders ålder hade ett järnintag under rekommenderat intag på 8 mg per dag. Två av dessa barn hade utvecklat järnbrist men eftersom järnbrist utvecklas över tid finns det en ökad risk bland dessa barn med ett otillräckligt intag av järn.

Det fanns inget samband mellan järnstatus och intag av komjölk bland ettåringarna. Intaget av komjölk var relativt litet och endast drygt hälften fick komjölk att dricka. De nya rekommendationerna gällande komjölk har troligen påverkat både mängden komjölk som barnet får samt åldern när komjölk introduceras som dryck i barnets kost. De flesta barn drack välling vid ett års ålder. Järnberikad välling och gröt utgjorde den största järnkällan av barnets totala järnintag. Detta indikerar att det är svårt för barn att få i sig tillräckligt med järn utan järnberikade produkter. Nästan hälften av föräldrarna beskrev att de hade upplevt problem under amningen och en fjärdedel tyckte att de hade problem vid matsituationerna när barnet var 12 månader. Detta är en viktig kunskap för dem som arbetar inom barnhälsovården då råd och stöd kan ges utifrån vetenskapen om att uppfödningssproblem är ett av de vanligaste problemen som föräldrar har under förskoleperioden.

För att bättre kunna möta föräldrars frågor och oro gällande matsituationerna samt att ge adekvat kostrådgivning behövs en förståelse av hur föräldrar upplever matsituationerna. Därför genomfördes en kvalitativ intervjustudie. Föräldrar till ettåringar utan kända uppfödningssproblem tillfrågades om att delta och 18 mödrar

tackade ja. Mödrarna delade också med sig upplevelser från matsituationerna med syskon. Intervjuerna spelades in på band, skrevs ner ordagrant och innehållet i texten analyserades. Alla mödrarna berättade att maten var en viktig del av deras föräldraskap och att det upptog mycket tid och engagemang. Första delen i analysen resulterade i antingen positiva eller negativa upplevelser.

De mödrar som beskrev att de hade positiva upplevelser berättade att de litade på barnets egen förmåga att reglera intaget av mat och de beskrev barnets signaler som lätta att tyda. Barnhälsovården hade gett råd vid behov samtidigt uttryckte mödrarna att det inte hade behövt något råd. De mödrar som upplevde matsituationerna negativa beskrev att de behövde kontrollera barnens intag då de inte trodde att barnen själva kunde reglera sitt intag. De uttryckte att de skapade rutiner och metoder för att få kontroll över barnet och att få barnet att äta mer. Detta gjorde att mödrarna ibland använde hot, belöning eller manipulerade med lek för att få kontroll över barnets intag. Mödrarna uttryckte att de behövt mer råd av barnhälsovården.

Sammanfattningsvis innebär detta att järnbrist existerar bland friska förskolebarn utan att några symtom identifierats varken av föräldrarna eller av barnhälsovården. Att identifiera faktorer som påverkar barnets järnstatus och järnintag måste anses viktigt ur ett barnhälsovårdsperspektiv för att förbättra kostrådgivningen och därmed öka möjligheten att förebygga järnbrist.

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REFERENCES

- Adish, AA. Esrey, SA. Gyorkos, TW. Jean-Baptiste, J. Rojhane, A (1999). Effect of consumption of food cooked in iron pots on iron status and growth of young children: a randomised trial. *Lancet*, **353**:712–16.
- Agget, PJ. Agostoni, C. Axelsson, I. Bresson, J-L. Goulet, O. Hernell, O. Koletzko, B. Lafeber, HL. Michaelsen, KF. Micheli, J-L. Rigo, J. Szajewska, H. Weaver, LT (2002). Iron Metabolism and Requirements in Early Childhood: Do We Know enough? A Commentary by the ESPGHAN Committee on Nutrition. *J Pediatr Gastroenterol Nutr*, **34**:337–345.
- Allen, LH. Rosado, JL. Casterline, JE. Lopez, P. Muñoz, E. Garcia, OP. Martinez, H (2000). Lack of hemoglobin response to iron supplementation in anemic Mexican preschoolers with multiple micronutrient deficiencies. *Am J Clin Nutr*, **71**:1485–94.
- Amsel, S. Boaz, M. Ballin, A. Filk, D. Ore, N (2002). Low Compliance of Iron Supplementation in Infancy and Relation to Socioeconomic Status in Israel. *Paediatrics*, **110**:410–411.
- Andrews, T (1999). Pulled between contradictory expectations: Norwegian mother/child service and the “new” public health discourse. *Critical Public Health*, **9**:269–285.
- Appoh, LY. & Krekling, S. (2005). Maternal nutritional knowledge and child nutritional status in the Volta Region of Ghana. *Maternal and Child Nutrition*, **1**:100–110.
- Arborelius, EU & Bremberg, SG. (2003). Supportive and non-supportive qualities of child health nurses’ contacts with strained infant mothers. *Scand J Caring Sci*, **17**: 169–175.
- Axelsson, I. Gebre-Medhin, M. Hernell, O. Jakobsson, I. Michaelson, KF. Samuelsson, G (1999). Delay cow’s milk intake as a beverage to infants until 10–12 months of age. *Läkartidningen*, **96**: 2206–2208.
- Baggens, C (2001). What they talk about: conversations between child health centre nurses and parents. *J Adv Nurs*, **36**:659–667.
- Baggens, C (2002). Nurses’ work with empowerment during encounters with families in child healthcare. *Critical Public Health*, **12**:351–363.
- Beauchamp & Childress (2001). *Principles of biomedical ethics*. Fifth edition, Oxford, University Press, Inc. New York.
- Birch, LL & Krahnstoeber, KK (2001). Family environmental factors influencing the developing behavioural controls of food intake and childhood overweight. *Paediatrics Clinics of North America*, **48**:(4):893–907.
- Blyth, R. Creedy, DK. Dennis, C-L. Moyle, W. Pratt, J. De Vries, SM (2002). Effect of Maternal Confidence on Breastfeeding Duration: An Application of Breastfeeding Self-Efficacy Theory. *Birth*, **29**(4):278–284.

- Briefel, RR. Reidy, K. Karwe, V. Jankowski, L. Hendricks, K (2004 a). Toddlers' Transition to Table Foods: Impact on Nutrient Intakes and Food Patterns. *J Am Diet Assoc*, **104**:S38-S44
- Briefel, RR. Reidy, K. Karwe, V. Devaney, B (2004 b). Feeding Infants and Toddlers Study: Improvements Needed in Meeting Infant Feeding Recommendations. *J Am Diet Assoc*, **104**:S31-S37.
- Brune, M. Rossander-Hulthén, L. Hallberg, L. Glerup, A. Sandberg, A-S (1992). Iron Absorption from Bread in Humans: Inhibiting Effects of Cereal Fiber, Phytate and Inositol Phosphates with Different Numbers of Phosphate Groups. *J Nutr*, **122**:442–449.
- Bogen, DL. Duggan, AK. Dover, GJ. Wilson, MH (2000). Screening for Iron Deficiency Anemia by Dietary History in a High-Risk Population. *Pediatrics*, **105**:1254–59.
- Bottoff, JL (1990). Persistence in breastfeeding: a phenomenological investigation. *J Adv Nurs*, **15**:201–209.
- Brown KH (2000). WHO/UNICEF Review on Complementary Feeding and Suggestions for Future Research: WHO/UNICEF Guidelines on Complementary Feeding *Pediatrics*, **106**: pp. 1290.
- Carruth BR & Skinner, JD (2000). Revisiting the Picky Eater Phenomenon: Neophobic Behaviours of Young Children. *J Am Coll Nutr*, **19**:771–780.
- Childs, F. Aukett, A. Darbyshire, P Ilett, S. Livera, N (1997). Dietary education and iron deficiency anaemia in the inner city. *Arch. Disease in Childhood*, **76**:144–147.
- Cohen, RJ. Brown, KH. Canahuati, J. Landa Riviera, L. Dewey, KG (1994). Effects of age of introduction of complementary foods on infant breast milk intake, total energy intake and growth: a randomised intervention study in Honduras. *Lancet*, **343**:288–93.
- Cohen, AR (1999). Choosing the Best Strategy to Prevent Childhood Iron Deficiency. *JAMA*, **281**(23):2247–2248.
- Cook, JD & Skikne, BS (1989). Iron deficiency: definition and diagnosis. *J Intern Med*, **226**:349–55.
- Cook, JD (1999). The Measurement of Serum Transferrin Receptor. *Am J Med Sci*, **318** (4): 269–76.
- Cook, JD. Flowers, CH. Skikne, BS (2003). The quantitative assessment of body iron. *Blood*, **101**(9): 3359–3364.
- Cooke, L (2004). The development and modification of children's eating habits. *British Nutrition Foundation*, **29**:31–35.
- Couper, RTL & Simmer, KN (2001). Iron deficiency in children: food for thought. *MJA*, **174**:162–163.
- Dahlberg, K. Drew, N. Nyström, M (2001). *Reflective life world research*. Studentlitteratur, Lund.

- Dallman, PR. Siimes, MA. Stekel, A (1980). Iron deficiency in infancy and childhood. *Am J Clin Nutr*, **33**: 86–118.
- Dallman, PR & Reeves, JD (1984). Laboratory Diagnosis of Iron Deficiency. In: Iron Nutrition in Infancy and Childhood. Editor Stekel, A. Nestlé Nutrition Workshop Series Volume 4. Raven Press, New York
- Dallman, PR. Siimes, MA. Stekel, A (1980). Iron deficiency in infancy and childhood. *Am J Clin Nutr*, **33**:86–118.
- Dallman, PR & Reeves JD (1984). Laboratory Diagnosis of Iron Deficiency. In: Stekel, A. editor. Iron Nutrition in Infancy and Childhood. Vevey/Raven Press, New York.
- DeMayer, E. & Adiels-Tengman, M. (1985). The prevalence of anemia in the world. *World Health Stat Q*, **38**:302–16.
- Dewey, KG (1998). Cross-cultural patterns of growth and nutritional status of breastfed infants. *Am J Clin Nutr*, **67**:10–7.
- Dimitriou, H. Stiakaki, E. Markaki, E-A. Bolonaki, I. Giannakopoulou, Ch. Kalmanti, M (2000). Soluble transferrin receptor levels and soluble transferrin receptor/log.ferritin index in the evaluation of erythropoietic status in childhood infections and malignancy. *Acta Paediatr*, **89**:1169–73.
- Dobbing J. (1990). Vulnerable periods in developing brain. In: Dobbing J. eds. *Brain Behaviour and Iron in the Infant Diet*. Springer-Verlag London, UK. 1–25.
- Domellöf, M. Dewey, KG. Lönnerdal, B. Cohen, RJ. Hernell, O (2002). The Diagnostic Criteria for Iron Deficiency in Infants Should Be Reevaluated. *J Nutr*, **132**:3680–3686.
- Dubois, L & Girard, M (2003). Social inequalities in infant feeding during the first year of life. The Longitudinal Study of Child Development in Quebec (LSCDQ 1998–2002). *Public Health Nutr*, **6**(8):773–783.
- Eden, AN & Mir, MA (1997). Iron Deficiency in 1- to 3-Year-Old Children. *Arch Pediatr Adolesc Med*, **151**:986–988.
- Emond, AM. Hawkins, N. Pennock, C. Golding, J (1996). Haemoglobin and ferritin concentrations in infants at 8 months of age. *Arch Dis Child*, **74**:36–39.
- Engelmann, MDM. Sandström, B. Michaelson, KF (1998). Meat Intake and Iron Status in Late Infancy: An Intervention Study. *J Pediatr Gastroenterol Nutr*, **26**:26–33.
- Engle PL & Zeitlin M (1996 1). Active feeding behaviour compensates for low interest in food among young Nicaraguan children. *J Nutr*, **126**(7):1808–16.
- Faber, M & Benade, AJS (1999). Nutritional status and dietary practices of 4–24-month-old children from a rural South African community. *Public Health Nutr*, **2**(2):179–185.
- Fagerli, RA. Wandel, M. Borch-Johnsen, B. Olsen, PT. Ek, J (1996). Diet and iron status among Norwegian and immigrant children. *Scand J Nutr*, **40**:S111-S113.

- Feelders, RA. Kuiper-Kramer, EPA. Van Eijk, HG (1999). Structure, Function and Clinical Significance of Transferrin Receptor. Review. *Clin Chem Lab Med*, **37**(1):1–10.
- Ferguson, BJ. Skikne, BS. Simpson, KM. Baynes, RD. Cook, JD (1992). Serum transferrin receptor distinguishes the anemia of chronic disease from iron deficiency anemia. *J Lab Clin Med*, **19**:385–90.
- Flowers, CH. Skikne, BS. Covell, AM. Cook, JD (1989). The clinical measurement of serum transferrin receptor. *J Lab Clin Med*, **114**:368–77.
- Fomon, SJ (1993). Iron. In: Fomon, SJ, editor. *Nutrition of normal infants*. Mosby, St. Louis, 239–60.
- Fomon, SJ. (2001). Feeding normal infants: Rationale for recommendations. *J Am Diet Assoc*, **101**(9): 1002–1005.
- Fomon, SJ. Nelson, SE. Serfass, RE. Ziegler, EE (2005). Absorption and Loss of Iron in Toddlers Are Highly Correlated. *J Nutr*, **135**:771–777.
- Freeman, VE. Mulder, J. van't Hof, MA. Hoey, HMW. Gibney, MJ (1998). A longitudinal study of iron status in children at 12, 24 and 36 months. *Public Health Nutr*, **1**(2):93–100.
- Freeman, V. van't Hof, M. Haschke, F and the Euro Growth Study Group (2000). Patterns of Milk and Food Intake in Infants From Birth to Age 36 Months: The Euro-Growth Study. *J Pediatr Gastroenterol Nutr*, **31**:S76-S85.
- Fuchs, GJ. Farris, RP. DeWier, M. Hutchinson, SW. Warriar, R. Doucet, H. Suskind, RM (1993). Iron status and intake of older infants fed formula vs cow milk with cereal. *Am J Clin Nutr*, **58**:343–8.
- Gibson, SA. (1999). Iron intake and iron status of preschool children: associations with breakfast cereals, vitamin C and meat. *Public Health Nutrition*, **2**(4):521–528.
- Gilbert, P (1998). Common feeding problems in babies and children: 2 *Professional Care of Mother and Child*, **8**(3):63–66.
- Gill, DG. & Segal, DS (1997). Follow-on formula in the prevention of iron deficiency: a multicentre study. *Acta Paediatr*, **86**:683–9.
- Grantham-McGregor, S & Ani, C (2001). A Review of Studies on the Effect of Iron Deficiency on Cognitive Development in Children. *J Nutr*, **131**:649S–668S.
- Grinder-Pedersen, L. Bukhave, K. Jensen, M. Højgaard, L. Hansen, M (2004). Calcium from milk or calcium-fortified foods does not inhibit nonheme-iron absorption from whole diet consumed over a 4-d period. *Am J Clin Nutr*, **80**:404–9.
- Gunnarsson, BS. Thorsdottir, I. Palsson, G. (2004). Iron status in 2-year-old Icelandic children and associations with dietary intake and growth. *Eur J Clin Nutr*, **58**:901–906.

- Gupta, S. Venkateswaran, R. Gorenflo, DW. Eler, AE. (1999). Childhood Iron Deficiency Anemia, Maternal Nutritional Knowledge, and Maternal Feeding Practices in a High-Risk Population. *Preventive Medicine*, **29**:152–156.
- Hallberg, L. Rossander-Hulthén, L. Brune, M. Gleerup, A (1992). Bioavailability in Man of Iron in Human Milk and Cow's Milk in Relation to Their Calcium Contents. *Pediatr Res*, **31**:524–527.
- Hallberg, L. (2001). Perspective on Nutritional Iron Deficiency. *Ann Rev Nutr*, **21**:1–21.
- Hallberg, L & Hulthén, L (2002). Perspective on iron absorption. *Blood Cells Mol Dis*, **29**:562–73.
- Hallberg, L. Hoppe, M. Andersson, M. Hulthén, L. (2003). The Role of Meat to Improve the Critical Iron Balance during Weaning. *Pediatrics*, **111**:864.870.
- Haschke, F. Pietsching, B. Vanura, H. Heil, M. Steffan, I. Hobiger, G. Schuster, E. Camaya, Z (1988). Iron intake and iron nutritional status of infants fed iron-fortified beikost with meat. *Am J Clin Nutr*, **47**:108–12.
- Hauk, YL & Irurita, VF (2002). Constructing Compatibility: Managing Breast-Feeding and Weaning from the Mother's Perspective. *Qualitative Health Research*, **12**(7):897–914.
- Hay, G. Sandstad, B. Whitelaw, A. Borch-Johnson, B (2004). Iron status in a group of Norwegian children aged 6–24 months. *Acta Paediatr*, **93**:592–598.
- Hedberg-Nyqvist, K & Kylberg, E (2000). The role of the Swedish Child Health Services in breastfeeding promotion. *Acta Paediatr. Suppl* **434**:57–64.
- Hobbie, C. Baker, S. Bayerl, C (2000). Parental Understanding of Basic Infant Nutrition: Misinformed Feeding Choices. *J Pediatr Health Care*, **14**:26–31
- Hörnell, A. Hofvander, Y. Kylberg, E (2001). Introduction of solids and formula to breastfed infants: a longitudinal prospective study in Uppsala, Sweden. *Acta Paediatr*, **90**:477–482.
- Hotz, C & Gibson, RS (2001). Complementary feeding practices and dietary intakes from complementary foods amongst weanlings in rural Malawi. *Eur J Clin Nutr*, **55**:841–849.
- Hotz, C & Gibson, RS (2005). Participatory nutrition education and adoption of new feeding practices are associated with improved adequacy of complementary diets among rural Malawian children: a pilot study. *Eur J Clin Nutr*, **59**:226–37.
- Huebers, HA. Beguin, Y. Pootrakul, P. Einspahr, D. Finch, CA (1990). Intact Transferrin Receptor in Human Plasma and Their Relation to Erythropoiesis. *Blood*, **75**(1): 102–7.
- Hulthén, L. Gramatkovski, E. Gleerup, A. Hallberg, L (1995). Iron absorption from the whole diet: Relation to meal composition, iron requirements and iron status. *Eur J Clin Nutr*, **49**:794–808.

- Hulthén, L. Lindstedt, G. Lundberg, P-A. Hallberg, L (1998). Effect of a mild infection on serum ferritin concentration-clinical and epidemiological implications. *Eur J Clin Nutr*, **52**:376–379.
- Hurtado, EK. Claussen, AH. Scott, KG (1999). Early childhood anemia and mild or moderate mental retardation. *Am J Clin Nutr*, **69**(1):115–119.
- Idjradinata, P & Pollitt, E (1993). Reversal of developmental delays in iron-deficient anaemic infants treated with iron. *Lancet*, **341**:1–4.
- Illet, S & Freeman, A. (2004). Improving the diet of toddlers of Pakistani origin: a study of intensive dietary health education. *J Fam Health Care*, **14**:16–19.
- Jain, S. Chobra, H. Garg, SK. Bhatnagar, M. Singh, JV (2000). Anemia in Children: Early Iron Supplementation. *Indian J Pediatr*, **67**:19–21.
- James, J. Lawson, P. Male, P. Oakhill, A (1989). Preventing iron deficiency in preschool children by implementing an educational and screening programme in an inner city practice. *BMJ*, **299**:838–840.
- Jansson, A. Isacson, Å. Kornfält, R. Lindholm, LH (1998). Quality in Child Healthcare. *Scand J Caring Sci*, **12**:195–204.
- Kapur, D. Sharma, S. Agarwal, KN (2003). Effectiveness of Nutrition Education, Iron Supplementation or Both on Iron Status in Children. *Indian Pediatrics*, **40**(12):1131–44.
- Karr, MA. Mira, M. Alperstein, G. Labib, S. Webster, BH. Lammi, AT. Beal, P (2001). Iron deficiency in Australian-born children of Arabic background in central Sydney. *Med J Aust*, **174**:165–168.
- Kattelman, K. Ho, M. Specker, BL (2001). Effect of timing of introduction of complementary foods on iron and zinc status of formula fed infants at 12, 24, and 36 months of age. *J Am Diet Assoc*, **101**:443–447.
- Khan, FA & Falck, S (2003). Barnhälsa och levnadsförhållande. Socialmedicinska enheten, UMAS, Malmö.
- Kohgo, Y. Niitsu, Y. Kondo, H. Kato, J. Tsushima, N. Sasaki, K. Hirayama, M. Numata, T. Nishisato, T. Urushizaki, I (1987). Serum Transferrin Receptor as a New Index of Erythropoiesis. *Blood*, **70**(6):1955–58.
- Kohl-Kumar, M (2001). Screening for Anemia in Children. AAP Recommendations – A Critique. *Pediatrics*, **108**(3):1–2.
- Koivisto, U-K & Sjöden, P-O (1996). Food and General Neophobia in Swedish Families: Parent-Child Comparison and Relationships with Serving Specific Foods. *Appetite*, **26**:107–118.
- Kuizon, MD. Madriaga, JR. Desnacido, JA. Cheong, RL. Perlas, LA (1996). Iron status of Filipino infants and preschoolers using plasma ferritin and transferrin receptor levels. *Southeast Asian J Trop Med Public Health*, **27**(2):342–9.
- Kwiatkowski, JL. West, TB. Heidary, N. Smith-Whitley, K. Cohen, AR (1999). Severe iron deficiency anemia in young children. *J Pediatr*, **135**(4):514–6.

- Lincoln, YS & Guba, EG (1985). *Naturalistic Inquiry*. Sage Publications, Beverly Hills, California pp 289-331.
- Lind, T. Lönnerdal, B. Persson, LÅ. Stenlund, H. Tennefors, C. Hernell, O (2003). Effects of weaning cereals with different phytate contents on hemoglobin, iron stores, and serum zinc: a randomized intervention in infants from 6 to 12 mo of age. *Am J Clin Nutr*, **78**:168–75.
- Lind, T. Hernell, O. Lönnerdal, B. Stenlund, H. Domellöf, M. Persson, L-Å (2004). Dietary Iron Intake Is Positively Associated with Hemoglobin Concentration During Infancy but not During the Second Year of Life. *J Nutr*, **134**:1064–1070.
- Livingstone, B (1997). Healthy eating in infancy. *Professional Care of Mother & Child* vol. 7(1): 9–11.
- Looker, AC. Dallman, PR. Carroll, MD. Gunter, EW. Johnson, CL (1997). Prevalence of Iron Deficiency in the United States. *JAMA*, **277**(12):973–6.
- Lozoff, B. Jimenez, E. Wolf, AW (1991). Long-term developmental outcome of infants with iron deficiency. *N Engl J Med*, **325**:687–94.
- Lozoff, B. Jimenez, E. Hagen, J. Mollen, E. Wolf, AW (2000). Poorer Behavioural and Developmental Outcome More than 10 Years After Treatment for Iron Deficiency in Infancy. *Pediatrics*, **105**(4):E51.
- Lozoff, B. De Andraca, I. Castillo, M. Smith, JB. Walter, T. Pino, P (2003). Behavioural and Developmental Effects of Preventing Iron-Deficiency Anemia in Healthy Full-Term Infants. *Pediatrics*, **112**:846–854
- Lutter, CK & Riviera JA (2003 a). Nutritional Status of Infants and Young Children and Characteristics of Their Diets. *J Nutr*, **133** 2941S–2949S
- Lutter, CK. & Dewey, KG (2003 b). Proposed Nutrient Composition for Fortified Complementary Foods. *J Nutr*, **133**:3011S–3020S
- Lönnerdal, B & Hernell, O (1994). Iron, zinc, copper and selenium status of breast-fed infants and infants fed trace element fortified milk-based infant formula. *Acta Paediatr*, **83**:367–73.
- Magnusson, M. Garrett, MJ. Sundelin, C (1999). Child health service's response to early feeding and behaviour problems: changes in parental perceptions 1970–93. *Acta Paediatr*, **88**:1094–1100.
- Male, C. Persson, LÅ. Freeman, V. Guerra, A. van't Hof, MA. Hascke, F and the Euro-Growth Iron Study Group. (2001). Prevalence of iron deficiency in 12-month old infants from 11 European areas and influence of dietary factors on iron status (Euro-Growth study) *Acta Paediatr*, **90**:492–498.
- Malmö Stad (2006). <http://malmo.se/faktaommalmopolitik/statistik/02utlandskbakgrund.4.33aee30d103b8f15916800028396.html-2006-02-21>.
- Manz, F. van't Hof, MA. Haschke, F (1999). The mother-infant relationship: who controls breastfeeding frequency? *Lancet*, **353**:1152

- Martins, S. Logan, S. Gilbert, R (2001). Iron therapy for improving psychomotor development and cognitive function in children under the age of three with iron deficiency anaemia. *The Cochrane Database of Systematic Reviews*. Issue 2. Art. No. CD001444. DOI:10.1002/14651858. CD001444.
- Marques, NM. Lira, PIC. Lima, MC. Da Silva, NL. Filho, MB. Huttly, SRA. Ashworth, A (2001). Breastfeeding and Early Weaning Practices in Northeast Brazil: A Longitudinal Study. *Pediatrics*, **108**(4):E66.
- McDade, TW. & Shell-Duncan, B (2002). Whole Blood Collected on Filter Paper Provides a Minimally Invasive Method for Assessing Human Transferrin Receptor Level. *J Nutr*, **132**:3760–3763.
- Mercer, RT & Ferketich, SL (1995). Experienced and Inexperienced Mothers' Maternal Competence during Infancy. *Research in Nursing & Health*, **18**:333–343.
- Michaelsen, KF. Larsen, PS. Thomsen, BL. Samuelson, G (1994). The Copenhagen cohort study on infant nutrition and growth: duration of breast feeding and influencing factors. *Acta Paediatr*, **83**:565–71.
- Michaelsen, KF. Milman, N. Samuelson, G (1995). A longitudinal study of iron status, growth velocity and dietary factors. *Acta Paediatr*, **84**:1035–44.
- Michaelsen, KF (2000). Cow's Milk in Complementary Feeding. *Pediatrics*, **106**(5):1302–3.
- Morad, A. (1998). Severe iron deficiency anemia (IDA) at the end of the 20th century. *J Pediatr Hematol Oncol*, **20** (4): 396.
- Morley, R. Abbott, R. Fairweather-Tait, S. MacFadyen, U. Stephenson, T. Lucas, A (1999). Iron fortified follow-on formula from 9–18 months improves iron status but not development or growth: a randomized trial. *Arch Dis Child*, **81**:247–252.
- Nguyen, ND. Allen, JR. Peat, JK. Beal, P. Webster, BH. Gaskin, KJ (2004). Iron status of young Vietnamese children in Australia. *J Paediatr Child Health*, **40**:424–429.
- Nordic Nutrition Recommendations (2004). 4th edition. Scanprint as Århus, Denmark.
- Norrby, A (1999). Järn och järnomsättning. In: *Blodsjukdomar*. Ed. Gahrton, G & Lundh, B. Natur och Kultur, Stockholm.
- Official Statistics of Sweden – Health and Diseases (2003). Breast-feeding, children born 2003. The National Board of Health and Welfare. Centre for Epidemiology.
- Olivares, M. Walter, T. Hertrampf, E. Pizarro, F. (1999). Anaemia and iron deficiency disease in children. *Br Med Bull*, **55**(3):534–543.
- Olivares, M. Walter, T. Cook, JD. Hertrampf, E. Pizarro, F (2000). Usefulness of serum transferrin receptor and serum ferritin in diagnosis of iron deficiency in infancy. *Am J Clin Nutr*, **72**:1191–5.
- Oti-Boateng, P. Seshadri, R. Petrick, S. Gibson, RA. Simmer, K (1998). Iron status and dietary iron intake of 6–24-month-old children in Adelaide. *J Paediatr Child Health*, **34**: 250–253.

- Oski, FA (1993). Iron deficiency in infancy and childhood. *N Engl J Med*, **329**(3):190–3.
- Pelto, GH (2000). Improving Complementary Feeding Practices and Responsive Parenting as a Primary Component of Interventions to Prevent Malnutrition in Infancy and Early Childhood. *Pediatrics*, Suppl.Nov**106**(5):1300.
- Pelto, GH. Levitt, E. Thairu, L (2003). Improving feeding practices: Current patterns, common constraints, and the design of interventions. *Food Nutr Bulletin*, **24**(1):45–82.
- Pelto, GH. & Freake, HC (2003). Social Research in an Integrated Science of Nutrition: Future Directions. *J Nutr*, **133**:1231–1234.
- Pelto, GH. & Backstrand, JR (2003). Interrelationships between Power-Related and Belief-Related Factors Determine Nutrition in Populations. *J Nutr*, **133**:297S–300S.
- Pelto, GH. Santos, I. Goncalves, H. Victoria, C. Martines, J. Habicht, JP (2004). Nutrition Counselling Training Changes Physician Behaviour and Improves Caregiver Knowledge Acquisition. *J Nutr*, **134**:357–362.
- Penny, ME. Creed-Kanashiro, HM. Robert, RC. Narro, MR. Caufield, LE. Black, R (2005). Effectiveness of an educational intervention delivered through the health services to improve nutrition in young children: a cluster-randomised controlled trial. *Lancet*, **365**:1863–72.
- Persson, LÅ. Lundström, M. Lönnerdal, B. Hernell, O (1998). Are weaning foods causing impaired iron and zinc-status in 1-year-old Swedish infants? A cohort study. *Acta Paediatr*, **87**:618–22.
- Phillips, F (2004). Nutrition and pre-school children. *Nutr Bull*, **29**:64–66.
- Picciano, MF. Smiciklas-Wright, H. Birch, LL. Mitchell, DC. Murray-Kolb, L. McConahy, KL. (2000). Nutritional Guidance Is Needed During Dietary Transition in Early Childhood. *Pediatrics*, **106**:109–114.
- Pridham, KF. Schroeder, M. Brown, R. Clark, R (2001). The relationship of mother's working model of feeding to her feeding behaviour. *J Adv Nurs*, **35**(5):741–750.
- Punnonen, K. Irjala, K. Rajamäki, A (1997). Serum Transferrin Receptor and Its Ratio to Serum Ferritin in the Diagnosis of Iron Deficiency. *Blood*, **89**(3):1052–57.
- Requejo, AM. Navia, B. Ortega, RM. Lopez-Sobaler, AM. Quintas, E. Gaspar, MJ. Osorio, O (1999). The Age at which Meat is First Included in the Diet Affects the Incidence of Iron Deficiency and Ferropenic Anaemia in a Group of Pre-school Children from Madrid. *Internat J Vit Nutr Res*, **69**(2):127–131.
- Santos, I. Victoria, CG. Martines, J. Goncalves, H. Gigante, DP. Valle, NJ. Pelto, G (2001). Nutrition Counseling Increases Weight Gain among Brazilian Children. *J Nutr*, **131**:2866–2873.

- SCB (1995). Reports on Statistical Co-ordination for the Official Statistics of Sweden 1995.
- SCB (2003). Reports on Statistical Co-ordination for the Official Statistics of Sweden 2003.
- Sellen, DW. (2001). Comparison of Infant Feeding Patterns Reported for Nonindustrial Populations with Current Recommendations. *J Nutr*, **131**:2707–2715
- Sethi, V. Kashyap, S. Seth, V (2003). Effect of Nutrition Education of Mothers on Infant Feeding Practices. *Indian J Pediatr*, **70**:463–466.
- Sheriff, A. Emond, A. Hawkins, N. Golding, J. (1999). Haemoglobin and ferritin concentrations in children aged 12 and 18 months. *Arch Dis Child*, **80**:153–157.
- Simondon, KB. Costes, R. Delaunay, V. Diallo, A. Simondon, F (2001). Children's height, health and appetite influence mothers' weaning decisions in rural Senegal. *Int J Epidemiol*, **30**:476–481.
- Singhal, A. Morley, R. Abbott, R. Fairweather-Tait, S. Stephenson, T. Lucas, A (2000). Clinical Safety of Iron-Fortified Formulas. *Pediatrics*, **105**(3):e38.
- Sjöberg, A. & Hulthén, L (2004). Assessment of habitual meal pattern and intake of foods, energy, and nutrients in Swedish adolescent girls: comparison of diet history with 7-day record. *Eur J Clin Nutr*, **58**:1181–1189.
- Skikne, BS. Flowers, CH. Cook, JD (1990). Serum Transferrin Receptor: A Quantitative Measure of Tissue Iron Deficiency. *Blood*, **75**(9):1870–6.
- Skinner, JD. Carruth, BR. Houck, KS. Coletta, F. Cotter, R. Ott, D. McLeod, M (1997). Longitudinal study of nutrients and food intakes of infants aged 2–24 months. *J Am Diet Assoc*, **97**:496–504.
- Soh, P. Ferguson, EL. McKenzie, JE. Homs, MYV. Gibson, RS (2004). Iron deficiency and risk factors for lower iron stores in 6–24-month-old New Zealanders. *Eur J Clin Nutr*, **58**:71–79.
- Stoltzfus, RJ. Kvalsvig, JD. Chwaya, HM. Montresor, A. Albanico, M. Tielsch, JM. Saviolo, L. Politt, E (2005). Effects of iron supplementation and anthelmintic treatment on motor and language development of preschool children in Zanzibar: double blind, placebo controlled study. *BMJ*, **323**:1–8.
- Sultan, AN & Zuberi, RW (2003). Late weaning: the most significant risk factor in the development of iron deficiency anaemia at 1–2 years of age. *J Ayub Med Coll Abbottabad*, **15**(2):3–7.
- Sundelin, C & Håkansson, A (2000). The importance of the Child Health Services to the health of children. *Acta Paediatr Suppl*, **434**:76–79
- Thane, CW. Walmsley, CM. Bates, CJ. Prentice, A. Cole, TJ (2000). Risk factors for poor iron status in British toddlers: further analysis of data from the National Diet and Nutrition Survey of Children aged 1.5–4.5 years. *Public Health Nutr*, **3**(4):433–440.

- Thorsdottir, I. Gunnarsson, BS. Atladottir, H. Michaelsen KF. Palsson, G (2003). Iron status at 12 months of age – effects of body size, growth and diet in a population with high birth weight. *Eur J Clin Nutr*, **57**:505–513.
- Trowbridge, F. & Martorell, R (2002). Summary and Recommendations. *J Nutr*, **132**. 875S–879S.
- Ulukol, B. Tezcan, S. Akar, N. Gökce, H. Cin, S (2004). Evaluation of erythropoiesis by serum transferrin receptor and ferritin in infants aged 0–6 months. *Pediatr Hematol Oncol*, **21**(4):293–305.
- Van't Hof, MA. Haschke, F & the Euro Growth Study Group (2000). The Euro-Growth Study: Why, Who, and How. *J Ped Gastroenterol Nutr*, **31**:S3-S13.
- Venkateswaran, R. Eyler, AE. Gorenflo, DW (1998). Iron deficiency and maternal feeding practices among high-risk urban children. *J Health Care Poor Underserved*, **9**(4):381–394.
- Virtanen, MA. Viinikka, LU. Virtanen, MKG. Svahn, JCE. Anttila RM. Kruises, T. Cook, JD Axelsson, IEM. Räihä, NCR. Siimes, MA (1999). Higher concentrations of serum transferrin receptor in children than in adults. *Am J Clin Nutr*, **69**:256–60.
- Wachs, TD. Creed-Kanashiro. H. Cueto, S. Jacoby, E (2005). Maternal Education and Intelligence Predict Offspring Diet and Nutritional Status. *J Nutr*, **135**:2179–2186.
- Walter, T. De Andraca, I. Chadud, P. Perales, CG (1989). Iron Deficiency Anemia: Adverse Effects on Infant Psychomotor Development. *Pediatrics*, **84**(1):7–17.
- Wharton, BA (1999). Iron deficiency in children: detection and prevention. Review. *Br J Haematol*, **106**:270–280.
- WHO/UNICEF/UNU (1994). Expert Consultation. Draft report on prevention of iron deficiency and anaemia program.
- WHO (1998). *Complementary Feeding of Young Children in Developing Countries. A Review of Current Scientific Knowledge*. Geneva Switzerland.
- WHO (2001). *Iron Deficiency Anaemia. Assessment, Prevention and Control*. WHO/NHD/01.3
- WHO (2002). *Nutrient adequacy of exclusive breastfeeding for the term infant during the first six months of life*. Geneva, Switzerland.
- Williams, A & Pinnington, LL (2003). Nurses' knowledge of current guidelines for infant feeding and weaning. *J Hum Nutr Diet*, **16**:73-80.
- Yeung, GS & Zlotkin, SH (1997). Percentile estimates for transferrin receptor in normal infants 9–15 mo of age. *Am J Clin Nutr*, **66**:342–6.
- Yeung, GS & Zlotkin, SH (2000). Efficacy of Meat and Iron-fortified Commercial Cereal to Prevent Iron Depletion in Cow Milk-fed Infants 6 to 12 Months of Age: A Randomized Controlled Trial. *Can J Public Health*, **91**(4):263–7.

- Yip, R (1990). The Epidemiology of Childhood Iron Deficiency: Evidence for improving Iron Nutrition among US children. In: Dobbing, J. editor. *Brain, Behaviour, and Iron in the Infant Diet*. Springer-Verlag, London, UK. 27–42.
- Yip, R (2002). Prevention and Control of Iron Deficiency: Policy and Strategy Issues. *J Nutr*, **132**:802S–805S.
- Zaffani, S. Cuzzolin, L. Meneghelli, G. Gangemi, M. Murgia, V. Chiamenti, G and Benoni, G. (2005). An analysis of the factors influencing the paediatrician-parents relationship: the importance of the socio-demographic characteristics of the mothers. *Child: Care, Health & Development*, **31**,5:575–580.
- Ziegler, EE. Fomon, SJ. Nelson, SE. Revouche, CJ. Edwards, BB. Rogers, RR. Lehman, LJ (1990). Cow milk feeding in infancy: Further observations on blood loss from the gastrointestinal tract. *J Pediatr*, **116**:11–8.
- Åkesson, A. Bjellerup, P. Vahter, M (1999). Evaluation of kits for measurement of the soluble transferrin receptor. *Scand J Clin Lab Invest*, **59**:77–82.