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Early eating habits in infants and their association with iron metabolism

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Abbreviations

ID – iron deficiency

IDA – iron deficiency anaemia

DNA – deoxyribonucleic acid

E% – total energy percent

EFSA – European Food Safety Authority

ESPGHAN – European Society for Paediatric Gastroenterology Hepatology and Nutrition

FFQ – Food Frequency Questionnaire

Hb – haemoglobin

IBM SPSS – programmatūras pakete statistiskajai analīzei (angļu val. *International Business Machines Statistical Package for the Social Sciences*)

IQR – interquartile range

Lf – lactoferrin

MCH – mean corpuscular haemoglobin

MCV – mean corpuscular volume

WHO – World Health Organisation

SN – standard deviation

SPSS – Statistical Package for the Social Sciences

sTfR – soluble transferrin receptors

Tf – transferrin

TfR – transferrin receptors

TIBC – total iron-binding capacity

control studies and 10 cohort studies) for a complete evidence base. Overall, the results of four studies revealed that infants consuming cow's milk have a higher risk of iron deficiency anaemia compared to the group of infants who received an artificial milk formula (relative risk = 3.76). Authors of this systematic review of literature have concluded that the intake of cow's milk by infants is related to the increased risk of iron deficiency. The restriction of intake of cow's milk may be an important preventive measure to ensure sufficient intake of iron by infants and young children. Authors of this publication emphasise the need for high quality informative materials, where parents would be explained how infants can take sufficient amount of iron with food (Griebler et al., 2016).

Meat eating habits in association with iron metabolism

The study results showed that the introduction of meat correlated with the level of haemoglobin in blood. The level of haemoglobin was within normal limits in almost all infants (95 %) for whom the intake of meat was introduced at the age of 7 months old or later. It is an interesting fact that infants for whom intake of meat was introduced at an early stage, at the age of 4–6 months old, the level of haemoglobin was reduced in 20 % of cases and within normal limits – in 80 % of infants, respectively. Another intervention study revealed an association between the use of meat and haemoglobin level. The results of the study suggest that depending on the amount of meat in the diet, the HB level in the blood changed considerably ($p = 0.008$). The infants who consumed less meat had a lower Hb concentration in the blood compared to the group of infants who receive more meat in the diet. However, no considerable difference was observed in SF and Tfr indicators, similar to this study (Engelmann et al., 1998).

Another cross-sectional study, which searched for correlations between the intake of meat and meat alternatives and iron metabolism, and between the intake of red meat and iron metabolism in older children, 12 to 36 months old, has not revealed statistically significant correlations between the intake of meat and meat alternatives and the level of serum ferritin in the blood. However, it has been proven that the intake of meat may reduce the risk of iron deficiency ($p = 0.03$) by 3 %, but if less meat is consumed, this may be a risk factor for iron deficiency. The study has not revealed a statistically significant correlation between the intake of red meat and iron metabolism indicators (Cox et al., 2016). A British study has also revealed an association between the intake of meat and better iron content in the body of older children (from 1.5 to 4.5 years old) (Thane et al., 2000).

These research results have not shown a statistically significant association between the frequency or amount of intake of meat and iron metabolism indicators in the blood. The statistically insignificant association at the level of 10 % was also contradictory. This might be explained by the fact that only slightly more than half (56 %) of consumed meat was red meat or meat rich in iron. Furthermore, another prospective cohort study studied whether more meat in the diet of children aged 4 to 24 months old would improve the metabolism of iron and other microelements in the body. The study cohort included 198 infants. A considerable association was observed in infants at the age of 12 months old between serum iron and meat intake ($p < 0.023$). A trend for an inverse association between haemoglobin concentration and the intake of meat was observed in the same age group ($p < 0.068$). The researchers have concluded that the intake of red meat has a positive effect on iron metabolism in infants at the age of 12 months old (Taylor et al., 2004).

A similar cross-sectional study was conducted in Jerusalem, including 263 healthy children aged 1.5 to 6 years old. The results of this survey showed that iron deficiency was observed 4 times more often in the group where children consumed very little meat than in children who consumed it 2 or more times per week ($p = 0.023$). However, such an association with iron deficiency was not observed in the case of the use of poultry. Researchers of this study have also concluded that iron deficiency is related to the insufficient intake of red meat. Another important conclusion from this study is related to poultry. Developed countries consume poultry much more often than red meat, which may become a risk factor for iron deficiency and increase its prevalence (Moshe et al., 2013).

A randomised double-blind controlled study in Germany studied whether the low content of meat in complementary food, which as accepted by European Union law, may increase the risk of iron deficiency in the period of complementary feeding in infants receiving adequate nutrition. In the group of healthy infants, who were breastfed or fed with artificial milk formula and received complementary food in accordance with nutritional recommendations, average iron metabolism biomarker indicators were within normal limits before (4 months), during (7 months) and after (10 months) the involvement with different amounts of consumed meat. No significant differences in biomarkers have been found between the groups where meat was consumed in increased and low amounts as might be expected. This study has also not revealed any difference in the intake of iron with food between high and low meat consumption groups. The researchers emphasise that the most important discovery is that after the primary data analysis, no justified evidence of disturbed iron metabolism when infants receive meat as complementary food in lower amounts than recommended by the European Union has been found. However, secondary analysis of data allows one to conclude that such a small amount of meat in the diet of many infants consuming breast milk in the first 4 to 6 months of their life in accordance with recommendations may increase the risk of iron metabolism disorders in the second half of the first year of their life (Dube et al., 2010).

Intake of legumes in association with iron metabolism

Although the infants living in Latvia do not consume legumes in large amounts, their use has shown statistically significant associations with iron metabolism. When studying the association of legumes with iron metabolism, it was observed that the intake of legumes reduced the level of serum ferritin in blood. This might be explained by the fact that the high content of phytates in legumes bind to iron and thus delay its absorption by the child's body (Dewey, 2013; Gibson et al., 2010; Lim et al., 2015).

Association of other factors with iron metabolism

Although eating habits are very important in the prevention of iron deficiency, it is important to study not only the impact of nutrition, but also the potential association of other factors with iron metabolism in infants. This study studies the associations with the use of iron medications during pregnancy or after giving birth, the mother's age, mother's education and the order of birth of the child. Statistically significant results were only evaluated for the association – the order of birth of the child and soluble transferrin receptors, where sTfR in first-born infants was within normal limits in more infants (62 %) compared to those who were not first-born (32 %).

Based on the data of this study as well as when examining the results of other studies, it is important to consider and study the association with the mother's age, the order of birth of the child, mother's nutrition and mother's health condition (Marques et al., 2016), mother's education, socioeconomic condition of the family (Thane et al., 2000), infant's sex (Soh et al., 2004), infant's weight, including excessive weight, obesity and other factors (Cox et al., 2016; Soh et al., 2004).

Study restrictions and challenges

During the study, several restrictions and challenges had to be faced. As to the assessment of data on nutritional value, there is always a possibility that the data provided by the parent or carer about the child's diet or daily nutrition doses are exaggerated or underestimated. Parents did not receive any remuneration for participation in the study (only dosing cups and food pyramid stickers were issued). At the same time, the contribution of parents in terms of time had to be rather extensive. They needed about 1.5–2 hours to collect all the necessary data for food frequency questionnaires (FFQ) and 24-hour dietary recall diaries. This might cause additional errors when providing data on the infant's daily nutrition. However, similar results obtained in both studies using different measuring instruments is most likely the evidence of the correctness of the methods used. The study is restricted by small samples of respondents in different age groups.

Conclusions

1. Eating habits of infants living in Latvia partially correspond to the guidelines of the Latvian Ministry of Health: diversity of food is observed, complementary feeding is initiated at the recommended age period, cow's milk is not used in amounts exceeding 600 ml per day, meat is introduced in the diet in a timely manner and in sufficient amounts. However, only 21 % follow the exclusive breastfeeding recommendation – its continuation in the first 6 months of life, 29 % breastfeed in the first 4 to 5.9 months, less than half (40 %) of all respondents did not breastfeed or breastfed for less than 4 months.
2. 63 % of infants at the age of 9–12 months old do not consume a sufficient about of iron with food and iron deficiency was observed in this group in 9.6 % of infants, while iron deficiency anaemia in 4.1 % of infants.
3. Associations with the following eating habits at an early age and other factors that affected iron metabolism in a favourable way have been found:
    a. a higher level of serum ferritin in the blood was observed in infants who received an artificial milk formula;
    b. a normal level of serum ferritin in the blood was observed in infants who consumed iron with food at least in the recommended dose (8 mg).
    c. a normal MCV level in the blood in the second half of the first year of life was observed in those whose mothers used iron medicines during pregnancy and after giving birth.
4. Associations with the following eating habits at an early age and other factors that affected iron metabolism in an unfavourable way, and could promote the development of ID and IDA, have been found:

a. lower level of iron in the blood was observed in infants for whom cow's milk was introduced at an early stage;
b. lower MCV level was also observed in those infants whose exclusive breastfeeding continued for at least the first 4 months of life compared to infants who were not exclusively breastfed for at least 4 months;
c. lower serum ferritin was observed in those infants who were breastfed and whose exclusive breastfeeding continued for at least the first 4 months of life, as well as in those infants in whose diet legumes have been introduced;
d. lower level of iron in the blood was observed in infants who were breastfed;
e. a higher level of soluble transferrin receptors in the blood was observed in infants who were not first-born compared to those who were first-born.

Nutrition recommendations for infants and young children

1. The recommended duration of exclusive breastfeeding is the first 6 months of life. If for some reason this is not possible, temporary exclusive breastfeeding is also desirable. When planning an exclusive breastfeeding, healthcare professionals should pay attention to the diet of pregnant and breastfeeding women, her iron metabolism, to ensure early prevention of iron deficiency or the risk of its occurrence during pregnancy and the postpartum period.
2. Breastfeeding should continue until 2 years of age.
3. It is recommended to introduce the first complementary food at the age of 4 to 6 months. It is important to consider that complementary food should not be introduced earlier than week 17 and not later than week 26.
4. Food consistency should change along with the child's age – from semi-liquid when starting complementary feeding to more solid food with pieces at about 8 months, at the age of 10 months at the latest.
5. Vegetables or porridge without gluten can be chosen as the first complementary food. When preparing puree, water or breast milk should be added as the liquid.
6. When starting complementary feeding, breastfeeding should continue, only in smaller amounts. The recommended number of complementary feedings is accepted assuming that 1 g of complementary food contains 0.8 kcal or more.
7. Complementary food shall start with one meal per day, offering some teaspoons of new food, then increase the number of meals and the size of the meal: 2 to 3 meals per day are recommended at the age of 6–8 months old, 3 to 4 meals for infants and children aged 9–24 months old. Offer 1 to

2 snacks between meals, depending on the child's appetite. It is assumed that an infant can eat about 30 ml of food per 1 kg of body weight.

8. Diversity should be observed when selecting food for complementary feeding in order to provide the infant's body with all the necessary nutrients. Meat, fish or eggs should be eaten every day. A vegetarian diet cannot provide all the necessary nutrients; therefore, the possibility to complement food with food supplements should be considered. Vegetables and fruit should be eaten every day. Food should contain a sufficient amount of fats. Drinks such as tea, coffee and sweetened drinks are not recommended. Juices should be used with caution; they can be replaced with other foods, which are richer in nutrients.
9. Vegetables, fruit and berries should be eaten every day. It is very important to observe diversity to provide the body with all the necessary vitamins. It is not recommended to add salt or sugar when preparing vegetables or fruit.
10. Meat should be introduced in the diet at an early stage – at the age of 6 months old, as one of the first complementary foods. Meat should be replaced with oily fish 1 to 2 times per week. Vegetable-potato-meat purees can be offered as one of the first meals (20–30 g of meat).
11. Dairy products should only be introduced as complementary food after iron-fortified foods, vegetables and fruit have been introduced in the period between 6 and 9 months old.
12. Cow's milk can be introduced from 6 months of age for the purposes of preventing allergy, adding it into meals in small amounts, and as a separate meal after the age of 12 months old. Milk and dairy products should have a high fat content, i.e. they should be full cream milk products.
13. Cereals are recommended as one of the first meals. Recommended cereals for meals are oat, rye, wheat, spelt, rice, buckwheat, maize, millet. The first offered cereal should be without gluten, for example, rice, buckwheat,

maize, millet. Later, cereals containing gluten can be used. Gluten should be introduced at the age of 4–12 months. Wholegrain products are preferable. Excessive use of cereals is not recommended, because fibre may negatively affect the absorption of iron by the body.

14. Eggs should be introduced at an early age, at the age of 4–6 months, to protect against the risk of allergy. Eggs may replace meat or fish from time to time. Eggs should be thermally processed before eating.
15. The inclusion of legumes in the diet depends on the individual peculiarities of the infant's body. The approximate age of inclusion of legumes starts from 7 months old. They should be taken at least once a week.
16. Exclusively breastfed infants do not usually need additional water, because breast milk provides a sufficient amount of liquid. Juices, both natural and produced, are not required in the first year of the infant's life.
17. During the second half of the first year of life, the total intake of liquid, including breast milk, should be 800 ml to 1000 ml.
18. At the age of 10 to 12 months old the infant should eat almost all food groups and gradually switch to family meals.
19. The energy distribution of nutrients in infants in the first half a year of life is as follows: proteins 10–15 E%, carbohydrates 40–45 E%, fats 50–55 E%. In the second half a year: proteins 5–15 E%, carbohydrates 45–55 E%, fats 40 E%.

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