Maternal & Child Nutrition

DOI: 10.1111/j.1740-8709.2010.00276.x

Original Article

Nutritional requirements during lactation. Towards European alignment of reference values: the EURRECA network

Victoria Hall Moran*, Nicola Lowe†, Nicola Crossland*, Cristiana Berti‡1, Irene Cetin‡, Maria Hermoso§, Berthold Koletzko§ and Fiona Dykes*

*Maternal & Infant Nutrition and Nurture Unit (MAINN) and †Centre for Applied Sport and Exercise Sciences, University of Central Lancashire, Preston, PR1 2HE, UK, ‡Unit of Obstetrics and Gynecology, Department of Clinical Sciences Hospital 'L. Sacco', and Center for Fetal Research Giorgio Pardi, University of Milan, Milano, Italy, and §Division of Metabolic Diseases and Nutritional Medicine, Dr von Hauner Children's Hospital, Ludwig-Maximilians-University of Munich, Munich, Germany

Abstract

There is considerable variation in reference values for micronutrient intake during lactation across Europe. The European Micronutrients Recommendations Aligned project aims to harmonize dietary recommendations throughout Europe. Recommended nutrient intakes during lactation are based on limited data and are often extrapolated from known secretion of the nutrient in milk with adjustments for bioavailability, so that differences between values can be partly ascribed to differences in methodological approaches and how these approaches were applied. Few studies have considered the impact of lactation on the mother's nutritional status. Rather, focus has been placed on the influence of maternal nutritional status on the composition of her breast milk. Most common nutritional deficits in breast milk are the result of maternal deficiencies of the water-soluble vitamins, thiamine, riboflavin and vitamins B6 and B12. Other than maternal vitamin A status, which to some extent is reflected in breast milk, concentrations of fat-soluble vitamins and most minerals in breast milk are less affected by maternal status. Factors relating to suboptimal maternal nutritional status during lactation include maternal age, diet and lifestyle factors and spacing of consecutive births. Recent research is providing new knowledge on the micronutrient requirements of lactating women. Identifying needs for research and improving understanding of the differences in values that have been derived by various committees and groups across Europe will enhance transparency and facilitate the application of dietary recommendations in policy-making decision and their translation into recommendations for lactating women. Given the wide variation in breastfeeding practices across Europe, making nutritional recommendations for lactating women is complex and challenging. Thus, it is crucial to first examine the cultural practices within and across European populations and to assess its relevance before making recommendations.

Keywords: lactation, breastfeeding, micronutrient, reference value, nutritional requirement, EURRECA.

Correspondence: Victoria Hall Moran, Maternal & Infant Nutrition and Nurture Unit, University of Central Lancashire, Preston PR1 2HE, UK. E-mail: vlmoran@uclan.ac.uk

[1]Supported by the Invernizzi Foundation Fellowship.

Introduction

There is considerable variation in reference values for micronutrient intake across Europe. The disparity is caused by various factors such as differences in underlying concepts, in the terminology used and in the methodologies and assumptions made to define micronutrient requirements and to derive reference values of intake (Doets *et al*. 2008).

The need for harmonization of dietary recommendations throughout Europe was recognized by the European Commission in 2005 (Ashwell *et al*. 2008).

The aim of harmonization is to improve understanding of the differences in values that have been derived by various committees and groups across Europe and to enhance their transparency to facilitate their application in policy making decision. The European Micronutrients Recommendations Aligned (EURRECA) Network of Excellence has four phases of activity. Research activity (RA) 1 evaluated best practice for assessing intake and status methods and collated current recommendations. RA 2 will apply best practice developed in RA 1 to population groups within a healthy population that may be vulnerable to micronutrient deficiencies. RAs 3 and 4 will develop and evaluate toolkits for dissemination of recommendations. Women who are pregnant or lactating have been identified by EURRECA as a vulnerable population group. While the nutrient requirements during pregnancy are discussed in this supplement by Berti and colleagues, the aim of this paper is to review specific aspects of healthy lactating women in relation to their micronutrient requirements.

Sources of disparity in nutrient recommendations across Europe

Great disparities exist between reference values for lactating women established in European countries (Tables 1,2). Some countries have published their own guidelines, some have harmonized their recommendations with other countries [e.g. the German-speaking countries (DACH) and the Nordic countries] and some have adopted recommendations suggested by others (e.g. Slovenia has adopted DACH recommendations). These disparities have arisen from the use of different concepts and sometimes different data and because the expert committees who set the recommendations often base their decisions on judgements concerning the quality of the available research (Pijls *et al*. 2009). As national reference values are reviewed at different time points, decisions may also be based on different scientific data (Doets *et al*. 2008). There is also discrepancy in the terminology used to describe reference values, creating difficulties with making comparisons across countries. For example, the UK's 'dietary reference values' are constructed around the estimated average requirement (EAR). The reference nutrient intake (RNI) is the value 2 standard deviations above the EAR. The RNI is equivalent to the population reference intake (PRI) used by the European Union (EU), and the recommended daily allowance (RDA) is used in other countries. Such divergent terminology and concepts can lead to confused messages that may have a serious impact on policy and significant health consequences (Pavlovic *et al*. 2007).

In relation to lactation specifically, as metabolic data upon which estimates of requirements are based are often lacking for physiological states such as lactation because of practical difficulties or ethical limitations in conducting research in women during these reproductive stages, differences between values can also be partly ascribed to differences in methodological approaches and how these approaches are applied (Atkinson & Koletzko 2007). For example, Atkinson and Koletzko (2007) compared the methods of extrapolation used to determine recommended intakes for vitamins A, C and E during lactation in the USA/Canada, the Caribbean, the EU, the Nordic countries (Denmark, Finland, Iceland, Norway and Sweden), the German-speaking countries (Austria, Germany and Switzerland) and the UK. They found that, although the general method of extrapolation was similar across reports, the reference values applied for nutrient composition of milk was often disparate,

Key messages

- The EURECCA network aims to harmonize the micronutrient recommendations for lactating women across Europe.
- The micronutrient requirements of lactating women are influenced by a range of factors including the intensity of lactation, maternal age, diet and lifestyle factors, and birth spacing.
- When making nutritional recommendations for lactating women attention must be paid to the social, cultural and economic factors that influence what women may eat.

Table 1. Recommended intake level for vitamins for lactating women (values are inclusive of any increment for lactation)

Country Units	Year	Reference	Reference value type	Vitamin A mg RE	Vitamin B6 mg	Vitamin C mg	Vitamin D μg	Vitamin E Mg	Thiamine mg	Riboflavin mg	Niacin mg NE	Vitamin B12 μg	Folate μg DFE
Albania	2005	[1]	RDA	1.3 (1.2)†	2	120 (115)	5	19	1.4	1.6	17	2.8	500
Belgium	2009	[2]	RDI	0.85	2	130	20	15	1.6	1.8	16	1.7	350
Bosnia and Herzegovina	2005	[3]	RDA	1.3 (1–6 m) 1.2 (7–12 m)‡	2.1	95 (1–6 m) 90 (7–12 m)	10	12 (1–6 m) 11 (7–12 m)	1.6	1.8 (1–6 m) 1.7 (7–12 m)	20	2.6	280
Bulgaria	2005	[4]	RI	1.2 (1.1)	2	*	5	19	1.4	1.6	17	2.8	500
Croatia	2004	[5]	RI	1.3	2	120	10	19	1.4	1.6	17	2.8	500
DACH countries§	2004	[6]	RNI or AI (vit E)	1.5	1.9	150	5	17	1.4	1.6	17	4	600
Estonia	2006	[7]	RI	1.1	1.6	100	10	11	1.7	1.7	20	2.6	500
France	2001	[8]	PRI or AI (folate, riboflavin, thiamine, vitamin D, vitamin E)	0.9	2	130	10	12	1.8	1.8	15	2.8	400
Greece	1993	[9]	PRI	0.9	1.4	70	10	*	1.1	1.7	16	1.9	350
Hungary	2005	[10]	Safe intake	1.2	2	120	10	19	1	1.7	16	2.6	425
Iceland	2006	[11]	RI	1.1	1.6	100	10	11	1.6	1.7	20	2.6	500
Ireland	1999	[12]	RDA	0.95	1.4	80	10	*	1.1	1.7	16	1.9	400
Italy	1996	[13]	RDA	0.95	1.4	90	10	*	1.1	1.7	16	1.4	350
Latvia	2001	[14]	Recommended average daily intake	1.3	2.2	150	10	12	1.6	2	20	3	300
Lithuania	1999	[15]	RDA	1.2	2	100	10	14	1.4	1.9	16	4	480
Macedonia – Former YR	2001	[16]	RDA	1.2	2	110	10	12	1.6	0.7	17.6	2.6	300
The Netherlands	1992	[17]	AI or RI (riboflavin, thiamine, B6, B12)	1.25	1.9	110	7.5	*	1.7	1.7	20	3.8	400
Nordic countries¶	2005	[18]	RI	1.1	1.6	100	10	11	1.6	1.7	20	2.6	500
Poland	2008	[19]	RDI or AI (vitamin D, E)	1.3 (1.2)	2	120 (115)	5	8	1.5	1.6	17	2.8	500
Portugal	2005	[20]	RNI or safe intake (vitamin A)	0.85	2	70	5	*	1.5	1.6	17	2.8	500
Russian Federation	1991	[21]	Recommended level of intake	1.2	2.3	115	12.5	12	1.8	1.97	16.8	3	300
Slovakia	1997	[22]	RDA	1.2	2.3	130	10	18	1.4	1.8	20	2.6	300
Slovenia	2004	[23]	RNI or AI (vitamin E)	1.5	1.9	150	5	17	1.4	1.6	17	4	600
Spain	2007	[24]	RI	1.3	2	85	10	17	1.1	1.7	18	2.6	500
UK	1991	[25]	RNI	0.95	1.2	70	10	*	1	1.6	15	2	260
WHO/FAO	2004	[26]	RNI	0.85	2	70	5	*	1.5	1.6	17	2.8	500

Values obtained from the web-based tool Nutri-RecQuest (described by Cavelaars *et al.* 2010). mg RE, mg retinol equivalent; mg NE, mg niacin equivalents; μg DFE, μg dietary folate equivalents; AI, estimated value for adequate intake; AR, adequate area of intake; PRI, population recommended intake; RDA, recommended daily allowance; RI, recommended intake; RNI, recommended nutrient intake; LL, lower limit; UL, upper limit. *Reference value is available but cannot be converted to the standard unit without making assumptions. †Values in parentheses indicate reference values for ≤18 years. ‡Indicating reference values for different stages of lactation. §DACH refers to reference intakes for Germany, Austria and Switzerland. ¶'Nordic countries' refers to Denmark, Finland, Norway and Sweden. Iceland has adapted these so is referred to separately. References: [1] Berisha A., Bader E., Deligia C and Claude Dop M, 2005. Albania. [2] Hoge Gezondheidsraad, Voedingsaanbevelingen voor België. Herziening 2009, HGR dossiernummer: 8309. [3] Public Health Institute of the Republic of Srpska, 2005. Bosnia and Herzegovina, entity: Republic of Srpska. [4] Ministry of Health, 2005. Bulgaria. [5] Croatian National Official Gazzette, 2004. Croatia. [6] German Nutrition Society (DGE), Austrian Nutrition Society (OGE), Swiss Society for Nutrition research (SGE), Swiss Nutrition Association (SVE) 2004. Germany, Austria, Switzerland. [7] Vaask, Sirje; Liebert, Tiiu; Maser, Mai; Pappel, Kaie; Pitsi, Tagli, Saava, Merileid; Sooba, Eve; Vihalemm, Tiiu, Villa, Inga, 2006. Estonia. [8] Martin A, Guest Editor-in-Chief, 2001. France. [9] Commission of the European Communities 1993 Nutrient and energy intakes for the European Community. Reports of the Scientific Committee for Food. [10] Antal M. 2005. Hungary. [11] The Public Health Institute of Iceland, 2006. Iceland. [12] Food Safety Authority of Ireland, 1999. Ireland. [13] LARN (1996) Livelli di Assunzione Raccomandati di Energia e Nutrienti per la Popolazione Italiana. Revision. Societá Italiana di Nutrizione Umana (SINU). [14] Latvian Food Center, 2001. Latvia. [15] Ministry of Health, 1999. Lithuania. [16] Ministry of Health and Republic Institute of Health Protection, 2001. The former Yugoslav Republic of Macedonia. [17] Food and Nutrition Council, 1992. Netherlands. [18] Nordic Council of Ministers, 2005. Denmark, Finland, Norway, Sweden. [19] National Food and Nutrition Institute, Wydawnictwo Lekarsie PZWL, Warsaw 2008. [20] World Health Organization (WHO), Food and Agriculture Organization of the United Nations 2004. WHO/FAO. [21] The Ministry of Health of the USSR, 1991. Russian Federation. [22] Ministry of Health, 1997. Slovakia. [23] German Nutrition Society (DGE), Austrian Nutrition Society (OGE), Swiss Society for Nutrition research (SGE), Swiss Nutrition Association (SVE) 2004. Germany, Austria, Switzerland. [24] Moreiras O, Carbajal AL, Cabera C 2007. Tablas de composicion de alimentos. Edicones Piramide 11a edicion revisada y ampliada. [25] Panel on DRVs of the Committee on Medical Aspects of Food Policy (COMA), 1991. United Kingdom. [26] World Health Organization (WHO), Food and Agriculture Organization of the United Nations 2004. WHO/FAO.

Table 2. Recommended intake level for minerals for lactating women (values are inclusive of any increment for lactation)

Country Units	Year	Reference	Reference value type	Calcium mg	Phosphorus mg	Potassium mg	Sodium mg	Magnesium mg	Iodine µg	Iron mg	Zinc mg	Selenium µg	Copper mg
Albania	2005	[1]	RDA	1000 (1300)	700 (1250)	5100	1500	320 (360)	290	9 (10)	12 (13)	70	1.3
Belgium	2009	[2]	RDI or Acceptable daily intake (K, Na)	1200	1000	3000 LL, 4000 UL	600 LL, 2000 UL	400	250	10	14	75	1.5
Bosnia and Herzegovina	2005	[3]	RDA	1200	1200	¶	¶	¶	¶	¶	¶	¶	¶
Bulgaria	2005	[4]	RI or AI (Ca, Na)	1000 (1300)	700 (1250)	5100	1500	320	290	9 (10)	12 (13)	70	1.3
Croatia	2004	[5]	RI	1000	700	*	*	310	290	9	12	70	1.3
DACH countries	2005	[6]	RNI or AI (Cu)	1000	900	*	*	390	260	20	10	30 LL, 70 UL	1 LL, 1.5 UL
Estonia	2006	[7]	RI	900	900	3100	*	280	200	15	11	55	1.3
France	2001	[8]	PRI or AI (Se)	1000	850	*	*	390	200	10	19	60	2
Greece	1993	[9]	PRI	1200	950	3100	*	*	160	10	12	70	1.35
Hungary	2005	[10]	Safe intake or suggested maximum intake (Na)	1200	930	3500	2000	450	200	15	13	75	1.4
Iceland	2006	[11]	RI	1000	750	3100	*	280	200	15	11	55	1.3
Ireland	1999	[12]	RDA	1200	950	3100	*	*	160	15	12	75	1.4
Italy	1996	[13]	RDA	1200	1200	3100	*	*	200	18	12	70	1.5
Latvia	2001	[14]	Recommended average daily intake	1200	1200	4000	3300	340	200	18	19	75	3
Lithuania	1999	[15]	RDA	1200	1200	2500	1500	380	200	20	15	*	*
Macedonia – former YR	2001	[16]	RDA	1200	1200	2000	1500	360	200	20	22	125	2.5
The Netherlands	1992	[17]	AR or AI (Ca, Fe)	1000	900 LL, 1800 UL	*	*	300 LL, 400 UL	*	20	18	75 LL, 150 UL	2 LL, 3.5 UL
Nordic countries	2005	[18]	RI	900	900	3100	*	280	200	15	11	55	1.3
Poland	2008	[19]	RDI or AI (Ca, K, Na)	1000 (1300)	700 (1250)	5100	1500	320 (360)	220 (290)	18	12 (13)	70	1.3
Portugal	2005	[20]	RNI	1000	*	*	*	270	200	§	§	35 (0–3 m) 35 (4–6 m) 42 (7–9 m)	*
Russian Federation	1991	[21]	Recommended level of intake	1200	1800	*	*	450	150	33	25	*	*
Slovakia	1997	[22]	RDA	1500	1500	*	*	390	300	20	16	70	2.5
Slovenia	2004	[23]	RNI or AI (Cu, Se)	1000	900	*	*	390	260	20	10	30 LL, 70 UL	1 LL, 1.5 UL
Spain	2007	[24]	RI	1500	700	3500	*	450	155	18	25	75	*
UK	1991	[25]	RNI or AI (Cu)	1250	990	3500	1600	320	140	14.8	13 (<4 m) 9 (>4 m)	75	1.5
WHO/FAO	2004	[26]	RNI	1000	*	*	*	270	200	§	§	35 (0–3 m) 35 (4–6 m) 42 (7–9 m)	*

Values obtained from the web-based tool Nutri-RecQuest (described by Cavelaars *et al.* 2010). mg RE, mg retinol equivalent; mg NE, mg niacin equivalents; µg DFE, µg dietary folate equivalents; AI, estimated value for adequate intake; AR, adequate area of intake; PRI, population recommended intake; RDA, recommended daily allowance; RI, recommended intake; RNI, recommended nutrient intake; LL, lower limit; UL, upper limit. *Reference value is available but cannot be converted to the standard unit without making assumptions. †Values in parentheses indicate reference values for 18 years. ‡Indicating reference values for different stages of lactation. §Reference value varies according to bioavailability. ¶Reference values are not referred to in the country-specific guidelines. References: [1] Berisha A., Bader E., Deligia C and Claude Dop M, 2005. Albania. [2] Hoge Gezondheidsraad, Voedingsaanbevelingen voor België. Herziening 2009, HGR dossiernummer: 8309. [3] Public Health Institute of the Republic of Srpska, 2005. Bosnia and Herzegovina, entity: Republic of Srpska. [4] Ministry of Health, 2005. Bulgaria. [5] Croatian National Official Gazzette, 2004. Croatia. [6] German Nutrition Society (DGE), Austrian Nutrition Society (OGE), Swiss Society for Nutrition research (SGE), Swiss Nutrition Association (SVE) 2004. Germany, Austria, Switzerland. [7] Vaask, Sirje; Liebert, Tiiu; Maser, Mai; Pappel, Kaie; Pitsi, Tagli, Saava, Merileid; Sooba, Eve; Vihalemm, Tiiu, Villa, Inga, 2006. Estonia. [8] Martin A, Guest Editor-in-Chief, 2001. France. [9] Commission of the European Communities 1993 Nutrient and energy intakes for the European Community. Reports of the Scientific Committee for Food. [10] Antal M. 2005. Hungary. [11] The Public Health Institute of Iceland, 2006. Iceland. [12] Food Safety Authority of Ireland, 1999. Ireland. [13] LARN (1996) Livelli di Assunzione Raccomandati di Energia e Nutrienti per la Popolazione Italiana. Revision. Societá Italiana di Nutrizione Umana (SINU). [14] Latvian Food Center, 2001. Latvia. [15] Ministry of Health, 1999. Lithuania. [16] Ministry of Health and Republic Institute of Health Protection, 2001. The former Yugoslav Republic of Macedonia. [17] Food and Nutrition Council, 1992. Netherlands. [18] Nordic Council of Ministers, 2005. Denmark, Finland, Norway, Sweden. [19] National Food and Nutrition Institute, Wydawnictwo Lekarsie PZWL, Warsaw 2008. [20] World Health Organization-(WHO), Food and Agriculture Organization of the United Nations 2004. WHO/FAO. [21] The Ministry of Health of the USSR, 1991. Russian Federation. [22] Ministry of Health, 1997. Slovakia. [23] German Nutrition Society (DGE), Austrian Nutrition Society (OGE), Swiss Society for Nutrition research (SGE), Swiss Nutrition Association (SVE) 2004. Germany, Austria, Switzerland. [24] Moreiras O, Carbajal AL, Cabera C 2007. Tablas de composicion de alimentos. Edicones Piramide 11a edicion revisada y ampliada. [25] Panel on DRVs of the Committee on Medical Aspects of Food Policy (COMA), 1991. United Kingdom. [26] World Health Organization (WHO), Food and Agriculture Organization of the United Nations 2004. WHO/FAO.

creating differences between reports in their recommended intakes.

It has been argued that the limited systematic physiological difference in populations and climate across Europe (with the possible exception of difference in sunlight exposure and consequent vitamin D recommendations) does not justify the existing disparities in nutrient recommendations. The EURRECA network aims to develop a common framework that uses consistent terminology in order to develop and maintain nutrient recommendations based on the best current evidence (Pijls *et al*. 2009).

Challenges to establishing nutritional recommendations for lactating women

Lactation is a highly demanding state for the mother with a nutritive burden considerably greater than that of pregnancy. The energy required to produce 1 L of milk is estimated to be approximately 700 kcal, and the milk secreted in 4 months of lactation represents an amount of energy roughly equivalent to the total energy cost of pregnancy (Cervera & Ngo 2001; Picciano 2003). Although it is well acknowledged that some of this requirement originates from the nutrients stored by the mother during pregnancy, there is a need for lactating mothers to increase their food intake in order to meet the elevated energy and micronutrient requirements (Cervera & Ngo 2001). Table 3 illustrates the percentage change in reference values for lactation from non-pregnant, non-lactating (NPNL) levels across Europe.

The duration and intensity of lactation (whether the infant is breastfed exclusively or only partially) may have an impact on a mother's nutritional status. For example, an exclusively breastfeeding woman has much greater energy and nutrient needs (with the exception of iron attributed to the potential protective effect of lactational amenorrhoea) than a woman who is only partially breastfeeding (Dewey 2004). These aspects of breastfeeding, however, have rarely been considered in studies of the nutritional impact of lactation in women. While the World Health Organization (WHO) recommends that infants should be exclusively breastfed for the first 6 months of life with breastfeeding continuing for up to 2 years of age or beyond (WHO 2003), in reality, there are wide deviations from this recommended norm both in terms of duration and intensity, especially in industrialized countries, challenging the meaningfulness of setting standard recommendations of nutrient intakes for lactation.

Factors that could have a modifying impact on nutritional recommendations and reference values in lactating women

Variability of breast milk

The calculation of recommended intakes during lactation often employs a factorial approach that simply sum the nutrient needs for a woman of similar periconceptional age who is not lactating with the amount of nutrient delivered into an average volume of breast milk, with adjustments for bioavailability in some cases (Atkinson & Koletzko 2007). While the composition of breast milk is thought to be relatively stable in well-nourished mothers, the infants' average daily intake of breast milk has been reported to vary between studies (WHO 1998). The volume of milk consumed by the infant at each breastfeeding has been shown to be dependent upon a number of factors, such as whether the breast that was being suckled was the more or less productive breast, whether the breastfeeding was unpaired, the time of day and whether the infant breastfed during the night or not (Kent *et al*. 2006).

Stage of lactation

Some countries/organizations investigated (Bosnia and Herzegovina, Portugal, the UK, WHO) have set reference values for different stages of lactation for some nutrients (see Tables 1,2). It is argued that the lactational period should not to be divided into different stages such as early and late lactation for the purpose of setting recommendations because evidence supports that, as during pregnancy, physiological adjustments in nutrient utilization occur during this period that generally compensate for the shifts

Table 3. Percentage change in micronutrient reference values during lactation compared to reference values for non-pregnant, non-lactating (NPNL) women (unless otherwise indicated the figure represent an increase from NPNL levels)

Country	Vitamin A	Vitamin B6	Vitamin C	Vitamin D	Vitamin E	Thiamine	Riboflavin	Niacin	Vitamin B12	Folate	Calcium	Phosphorus	Potassium	Sodium	Magnesium	Iodine	Iron	Zinc	Selenium	Copper
Albania	86 (71)	54	33 (28)	*	27	27	45	21	17	25	0 (30)	0 (79)	9	0	3 (16)	93	–50 (–44)	50 (63)	27	44
Belgium	70	11	18	60	0	45	50	14	21	75	33	25	0	0	11	25	–26	75	25	25
Bosnia and Herzegovina	63 (50)	31	58 (50)	100	50 (38)	45	38 (31)	33	30	56	50	50	*	*	*	*	*	*	*	*
Bulgaria	71 (57)	54	*	0	27	*	45	21	17	25	0 (30)	0 (79)	9	0	14	93	–50 (–44)	50 (63)	27	44
Croatia	63	0	100	100	90	0	0	–6	180	150	25	*	*	*	3	93	–36	*	40	13
DACH countries	88	58	50	0	42	40	33	31	33	50	0	29	*	*	30	30	33	43	0	0
Estonia	57	23	33	33	38	55	31	33	30	67	13	50	0	*	0	33	0	57	38	44
France	50	33	18	100	0	64	20	36	17	33	11	13	*	*	8	33	–38	90	20	33
Greece	50	27	56	100	*	22	31	14	36	75	*	73	0	*	*	23	–32	71	40	23
Hungary	50	54	33	100	29	11	31	14	30	42	50	50	0	0	50	33	0	44	25	27
Iceland	57	23	33	0	38	45	31	33	30	25	25	25	0	*	0	33	0	57	38	44
Ireland	58	27	33	100	*	22	31	14	36	33	50	73	0	*	*	23	–7	71	36	27
Italy	58	27	50	100	*	22	31	14	27	75	20	20	0	*	*	33	0	71	27	25
Latvia	30	10	50	100	0	33	25	25	0	0	0	0	0	0	–3	0	0	36	25	0
Lithuania	50	104	67	100	40	*	36	–6	33	60	20	33	0	0	27	33	33	25	*	*
Macedonia – Former YR	50	33	57	100	50	45	250	40	30	50	50	50	*	0	29	33	33	83	0	0
The Netherlands	56	27	57	200	*	55	55	54	36	33	0	*	*	*	27	*	33	140	13	10
Nordic countries	57	23	33	33	38	45	31	33	30	25	13	50	0	*	0	33	0	57	38	44
Poland	86 (71)	54	60 (53)	0	0	36	45	21	17	25	0 (30)	0 (79)	9	0	3 (16)	47 (93)	–44	60 (63)	27	4
Portugal	70	54	56	0	*	36	45	21	17	25	0	*	*	*	23	33	*	*	*	*
Russian Federation	33	28	53	400	50	48	34	4	0	50	50	50	*	*	13	0	*	67	*	*
Slovakia	41	26	59	33	29	27	15	18	30	50	61	25	*	*	11	81	20	45	35	25
Slovenia	88	58	50	0	42	40	33	31	33	50	0	29	*	*	30	30	33	43	0	0
Spain	63	25	42	100	42	22	21	20	30	25	88	0	0	*	36	41	0	67	36	*
UK	58	0	75	*	*	25	45	15	33	30	79	80	0	0	19	0	0	86 (36)	25	25
WHO/FAO	70	54	56	0	*	36	45	21	17	25	0	*	*	*	23	33	*	*	*	–

Values in parentheses indicate percentage change for lactating women aged ≤18 years (Albania, Bulgaria and Poland), or values at different stages of lactation (Bosnia and Herzegovina and the UK). *Unable to calculate percentage increase as either reference value is available but cannot be converted to the standard unit without making assumptions; reference value varies according to bioavailability; reference value is not referred to in the country specific guidelines.

in nutrient requirement with stages of lactation. Atkinson & Koletzko (2007) assert that the grading reference values do not appear to be based in strong science and having more than one reference value for lactation is impractical to implement.

Maternal age

Several countries have set separate reference values for some micronutrients (typically vitamins A and C, calcium, phosphorus, magnesium, iron and zinc) for adolescent and adult lactating mothers (see Tables 1,2). It has be suggested that, as adolescence is a period of rapid growth (approximately 50% of adult body weight and 15% of final adult height is attained during this stage of the life cycle; Rogol *et al.* 2000), the additional nutritional demands of pregnancy and lactation may have a significant impact on the nutritional status of adolescent mothers and their breast milk, particularly those who are undernourished (Hall Moran 2007). In studies of adolescents in Bangladesh, for example, linear growth ceased during pregnancy and lactation, and lean body mass and percent body fat declined by 6 months post partum (Rah *et al.* 2008). Lower ponderal and body compositional measures were exhibited in those adolescents whose infants survived through the neonatal period compared with those who experienced a fetal loss or neonatal death, suggesting a depletion of maternal energy and nutrient reserves to meet the demands of both pregnancy and lactation (Rah *et al.* 2010). In contrast, Scholl *et al.* (1990, 1993) demonstrated that still-growing US adolescents continued to grow in stature and accrue fat mass during pregnancy and lactation. However, these young mothers had infants with lower birthweight, particularly when the mother continued to accrue higher amounts of arm or subscapular fat late in gestation. Scholl *et al.* (1993) suggest that, instead of mobilizing fat reserves late in pregnancy to enhance fetal growth, adolescent mothers appeared to be reserving them for their own continued development.

Other research has found that breastfeeding during adolescence may have a protective role on bone mass acquisition. While bone accretion rates peak during pubertal growth because of associated hormonal changes and adolescents experience bone mineral density (BMD) loss during lactation, this effect seems to be transient with subsequent repletion of BMD once breastfeeding is ceased (Bezerra *et al.* 2004). Chantry *et al.* (2004) reported that adjusted BMD between ages 20 and 25 were 5–10% higher in women who had breastfed as adolescents compared with those who had not. As higher peak BMD achieved during adolescence protects against postmenopausal osteoporosis (Rozen *et al.* 2003), breastfeeding during adolescence may have a protective role against this disease. It has been suggested that the mechanisms of BMD repletion (thought to be attributed to the reversal of hormonal changes that caused bone loss during lactation; Kalkwarf 1999) may have a larger physiologic effect when bone mineral is still accruing (Chantry *et al.* 2004).

It has been suggested that adolescents who are still growing have an increased demand for zinc during lactation (Institute of Medicine 2001). Meeting zinc demands during lactation will depend on the dietary supply, bioavailability and the capacity for adaptation of zinc metabolism. While recent evidence suggests that the biochemical responses of zinc to lactation are similar in adolescents and adults, significant correlations have been found between the activity of zinc-dependent enzymes and plasma zinc in adolescents, which may suggest a limiting action of poor maternal zinc status on the metabolic adaptation capacity of this population (Maia *et al.* 2007).

It is clear that, while there is some evidence to suggest that the nutritional demands of lactation may have a differential impact on the nutritional status of adolescent women, further research is needed to clarify this.

Birth spacing and the recuperative interval

Reference values for lactation do not account for the influence of birth spacing on maternal nutritional status. There is a large nutritional burden associated with closely spaced consecutive births, particularly when lactation overlaps with pregnancy (Adair 1993). The duration and intensity of lactation influences the ability of the mother to replete her nutrient reserves

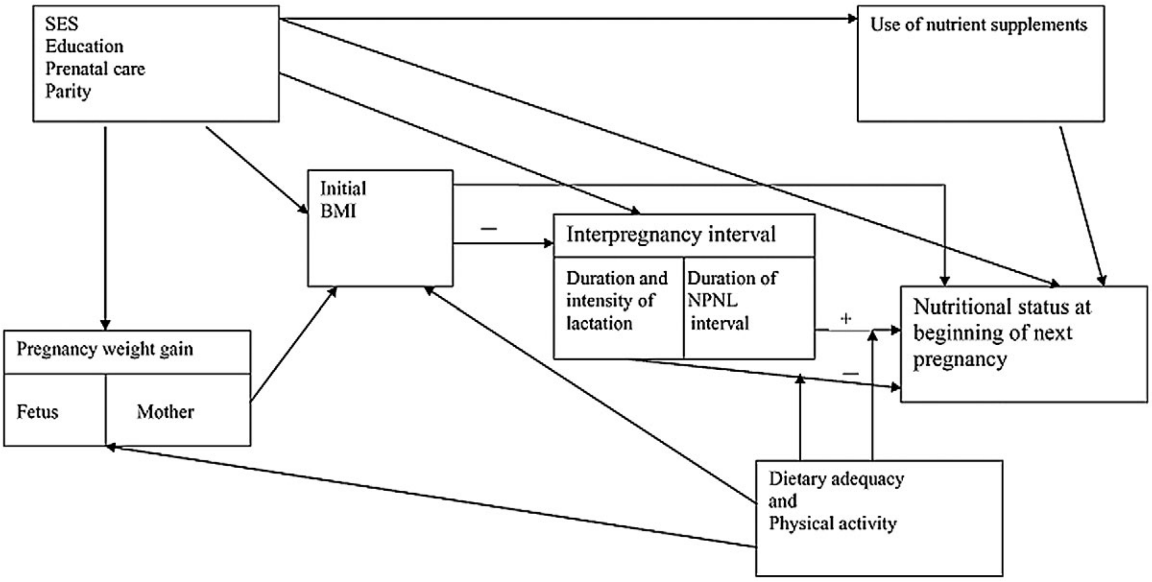

Fig. 1. Conceptual model for the relationship between interpregnancy interval and maternal nutritional status. BMI, body mass index; NPNL, non-pregnant, non-lactating; SES, socio-economic status (reproduced with permission from Dewey & Cohen 2007).

during the interval between pregnancies (Dewey & Cohen 2007). Pregnancies with short 'recuperative intervals' (defined as the amount of time that the woman was not lactating prior to the next conception) therefore are particularly vulnerable to nutrient depletion. The complex interaction between the factors that affect maternal nutritional status during short recuperative intervals is shown in Fig. 1 (Dewey & Cohen 2007). The nutritional consequences of a short interpregnancy interval (whether combined with duration and intensity of lactation or not) are influenced by many factors, such as mother's BMI, dietary adequacy, physical activity level, socio-economic status, education level, access prenatal care, parity and morbidity. It is likely that the relationship is context-specific, with positive associations perhaps more evident in undernourished populations (for a more detailed discussion, refer to Dewey & Cohen 2007).

The majority of studies on recuperative interval have investigated its impact on the infant, with longer birth intervals associated with a lower risk of malnutrition and stunting in some populations. The more limited data on maternal outcome have yielded inconclusive results. A recent systematic review found only three studies that considered the effect of recuperative interval on maternal anthropometric status; none looked at the influence on maternal anaemia or micronutrient status (Dewey & Cohen 2007). Recuperative interval was found to be positively associated with maternal thigh skinfold measurements (Merchant *et al*. 1990) and pregnancy weight gain (Pebley & DaVanzo 1993) in studies conducted in developing countries. Although weight gain between pregnancies in undernourished populations may be a positive maternal outcome, it may not be true in developed countries where pre-pregnancy non-obese weight has been positively associated with increased risk of perinatal complication (Cnattingius *et al*. 1998, Villamor & Cnattingius 2006).

Factors based on diet and lifestyle

Aspects of dietary patterns and lifestyle, such as quality of foods, their combination with other foods and their processing and storage, can produce differences in nutrient absorption and metabolism, and therefore have an impact on nutritional recommendations and reference values. Little research has been conducted on the wide variety of dietary factors that could have a specific impact on lactating women.

There is some case study evidence that has demonstrated severe vitamin B12 deficiency in exclusively breastfed infants of vegetarian and vegan mothers (Weiss *et al*. 2004; Baatenburg de Jong *et al*. 2005; Wagnon *et al*. 2005). Infants of vegetarian and vegan mothers have low vitamin B12 levels at birth, and this appears to be perpetuated if the vitamin B12-deficient mother breastfeeds her infant (Specker *et al*. 1990). There is little information regarding the long-term neurological effects of such deficiency, but these may include intellectual impairment, severe disturbance of gait and epilepsy (Graham *et al*. 1992). Vegetarianism is particularly common in adolescent girls, with a prevalence of between 8% and 37% (Worsley & Skrzypiec 1998). In addition, vegetarian teenagers are also more likely to exhibit health-compromising dietary behaviours that could further compound the nutritional challenge of lactation in this particularly vulnerable population, such as frequent dieting, binging, purging and laxative use for weight control (Neumark-Sztainer *et al*. 1997; Perry *et al*. 2001; Bas *et al*. 2005) and alcohol use (Greene-Finestone *et al*. 2008). Studies have yet to be conducted on the particular influence of vegetarian diets on the nutritional status of lactating adolescents.

The negative influence of maternal smoking on breastfeeding duration has been well described in the literature (Horta *et al*. 2001) and has been shown even after adjusting for socio-economic group and education level (Hopkinson *et al*. 1992). Some studies have suggested that smoking reduces daily milk output by approximately 250–300 mL (Vio *et al*. 1991; Hopkinson *et al*. 1992), possibly related to suppressed prolactin production in smokers (Anderson & Schioler 1982; Widstrom *et al*. 1991). While it is well documented that smoking has a negative impact on the smokers' nutritional status, particularly antioxidant nutrients (Gibson 2005), little is known about the influence of smoking on milk composition. It has been suggested, however, that smoking is associated with significant reductions in milk fat concentration (Vio *et al*. 1991; Hopkinson *et al*. 1992). The reduction in milk volume and fat content has been given as an explanation as to why women who smoke cease to breastfeed earlier than those who do not smoke (Hopkinson *et al*. 1992). However, it is not yet clear whether social and behavioural differences between smokers and non-smokers play a greater role in early cessation of breastfeeding than physiological factors. In their review, Amir & Donath (2002) claimed that, as women who smoke are less likely to intend to breastfeed and less likely to seek help with breastfeeding problems than non-smoking mothers, it cannot be assumed that the relationship between smoking and breastfeeding duration is a wholly physiological one. Recent qualitative research emphasized the importance of the role of psychosocial factors reporting that the reasons given by women who ceased to breastfeed earlier related to their perceptions that smoking while breastfeeding constituted a strong risk of harming their baby (Goldade *et al*. 2008).

Socio-economic and cultural factors

It is recognized that lactation is not simply a matter of transmitting nutrition from mother to infant but a crucial relational process between mother and child (Dykes & Hall Moran 2006). Thus, when assessing nutritional requirements for lactating women, it is important to consider the socio-cultural, political and economic constraints upon women in securing optimum nutritional standards for themselves and their children. This is a crucial perspective as maternal dietary and infant feeding practices relate significantly to cultural norms and associated constraints (Sellen 2001; Dykes 2005; Spiro 2006; Scavenius *et al*. 2007; Bhutta *et al*. 2008); this explains the inevitable wide variations in practice across the industrialized world, with Europe being no exception.

Some cultural practices affect micronutrient status through routes other than access to foods and dietary intake. For example, South Asian Muslim women living in Europe may adopt a dress code of complete or partial covering of the body. They are thus exposed to little or no sunlight, affecting their vitamin D status, which can have serious consequences during pregnancy and lactation. Some cultural groups prefer to avoid giving colostrum to the baby as it is seen as old milk, a waste product, contaminating and even poisonous (Wambach & Riordan 2010). Weaning practices (timing and spacing) of complementary foods vary enormously across cultural groups, and these practices inevitably affect the course, style and duration of lactation. In many European communities, solid foods and soups are introduced well before the recommended 6 months (WHO 2000).

There is a range of deeply embedded cultural practices that will influence what the mother actually selects to eat during lactation. For example, Hispanic cultures, Chinese and some South Asian groups adhere to a set of implicit rules around 'hot' and 'cold' foods (Davis 2001; Wambach & Riordan 2010). This does not relate to temperature but rather to a set of foods that are considered to affect the body in particular ways. The practice of giving herbs and galactogogues (foods thought to enhance the quality and/or quantity of milk) to the mother is a widespread cultural practice that varies from community to community. These practices are commonly harmless but in some cases may be problematic, for example, taking some alcoholic drinks to stimulate lactation.

Socio-economic considerations at both macro- and micro-levels influence the dietary intake of women so for example, mothers living in conditions of poverty may have little opportunity to obtain foods known to be important during pregnancy and lactation (Coufopoulos & Hackett 2009; Stapleton & Keenan 2009). These factors create challenges for such individuals in their achievement of the nutrient reference value recommendations.

Influence of maternal nutritional status on breast milk composition

Few studies have considered the impact of lactation on maternal nutritional status. Rather, focus has been placed on the influence of maternal nutritional status on the composition of her breast milk. The micronutrient content of breast milk is relatively constant. Although it is generally believed that its nutritional composition is preserved by homeostatic and nutrient transport mechanisms that can compensate for increases and moderate decreases in maternal nutrient supply, for many micronutrients, there is point at which maternal dietary insufficiency will have consequences in terms of maternal status and supply of nutrients to the infant via breast milk. There has been very little research conducted to help our understanding of the situations in which maternal milk mineral concentration is low; however, it is likely that maternal malnutrition may impair mammary gland function and the normal transport processes involved in the transfer of micronutrients into the milk (Lonnerdal 2000).

Minerals

For many minerals, the infant is well protected by maternal homeostatic processes such that moderate deficiency or excessive dietary intake does not significantly alter the levels of these micronutrients in the mother's milk (Domellof *et al*. 2004). Many minerals are transferred into milk by active transfer rather than passive diffusion, and this process compensates for variations in maternal mineral status. One notable exception to this is selenium for which breast milk selenium concentration correlates well with maternal selenium status (Lonnerdal 2000).

Many European countries recommend an increase of at least 33% in iodine intake from NPNL levels (Table 3). This increase is required to accommodate the changes in maternal thyroid metabolism to support lactation, to supply sufficient iodine for milk to meet the needs for growth and development of the infant and to ensure that pregnant and lactating women do not suffer from iodine deficiency post partum (WHO 2007). However, Zimmermann & Delange (2004) report that national surveys from European countries reveal the median dietary intake of iodine in women of child bearing age is around half of the recommended levels. The iodine content of milk is dependent upon the mother's iodine intake, although there are compensatory mechanisms that enhance iodine uptake by the mammary gland of iodine deficient mothers. Optimally, the iodine content of mature milk should be in the range of 100–150 $\mu g\ dL^{-1}$; above 75 $\mu g\ L^{-1}$ is sufficient, but may fall to values below 30 $\mu g\ L^{-1}$ in areas with endemic goitre (Azizi & Smyth 2009). When maternal iodine status is inadequate, the uptake of iodine by the mammary gland increases during lactation, creating a deterioration of the maternal iodine status by the sequestration of some of the maternal iodine pool to the breast milk (Delange *et al*. 1988). In women with marginal iodine status, the demands of lactation can precipitate clinical and biochemical symptoms, including increased thyroid volume, altered thyroid hormone levels and impaired mental function (Eltom *et al*. 2000; Dorea 2002). Despite these effects, there is currently insufficient evidence to substantiate the benefits of zinc supplementation in lactating women (Hess & King 2009).

An adequate supply of zinc is essential for the normal growth and development of the fetus and infant post partum. The high level of zinc in colostrum, which is 17 times higher than that in blood, illustrates the importance of zinc in the development of a newborn (Almeida *et al*. 2008). Most European countries recommend that zinc intake is increased by at least 50% from NPNL levels (Table 3). Current WHO recommendations for zinc intake during pregnancy and lactation range from 4.3 to 19 mg per day, depending upon months post partum and the bioavailability of zinc from the diet (WHO/Food and Agriculture Organization of the United Nations (FAO) 2004). In a randomized double-blind, placebo-controlled supplementation study of healthy women, Krebs *et al*. (1995) reported that zinc concentration of milk declines rapidly in the first 3 months post partum from 59.4 to 16.7 μmol L^{-1}, and this was not influenced by dietary supplementation with 15 mg Zn per day. It appears that an intake of 13 mg Zn per day during lactation is adequate, and increasing intakes beyond this does not resulted in increased milk zinc concentration (Moser-Veillon & Reynolds 1990; Hambidge & Krebs 2007). A number of studies of lactating women with marginal zinc status have revealed that homeostatic mechanisms can compensate for low maternal dietary zinc intakes. The proportion of dietary zinc absorbed in such women has been shown to increase by over 70% compared with non-lactating women or pre-conception values (Jackson *et al*. 1988; Sian *et al*. 2002). Evidence for a homeostatic response to low dietary zinc intake was further illustrated in a study that reported that despite having dietary zinc intakes that were 42% of the reference value, the zinc status of lactating women (assessed using plasma zinc concentrations) was not significantly lower than those of non-lactating women (Moser & Reynolds 1983). While such mechanisms act to enhance maternal zinc availability for fetal growth and milk zinc excretion, a consequence is that maternal reproductive function may be compromised (Hess & King 2009).

The transfer of calcium to breast milk is a physiologic response to lactation and facilitated by the upregulation of calcium absorption by the mother, conservation of excretion via kidney and mobilization of calcium from the bone (Ritchie *et al*. 1998). As a consequence, bone mineral density loss has been shown to occur during lactation (Karlsson *et al*. 2001), but this effect seems to be transient and seems to be unrelated to calcium intake. Reference values for calcium intake during lactation throughout Europe range from no additional intake to an increase of over 80% from NPNL levels (Table 3). In those countries that have set differential recommendations for lactating adolescents, reference values for calcium exceed those of adult lactating women. There is little evidence, however, to suggest that there exists a significant association between the mother's calcium intake (whether supplemented with calcium or not) and levels in breast milk. A randomized controlled trial of pregnant and lactating women in Gambia revealed that, despite having low dietary intakes of calcium (300–400 mg d^{-1}) and low breast milk concentrations, calcium supplements had no significant benefit in terms of breast milk concentration (Jarjou *et al*. 2006). Nor is there evidence to suggest that supplements prevent bone loss during lactation or the recovery of calcium status when breastfeeding is ceased (Kalkwarf & Specker 2002).

Many European countries recommend that iron intake is reduced during lactation compared with NPNL levels, albeit slightly less so for adolescent mothers (Table 3). This is because women who exclusively breastfeed are usually amenorrhoeic for at least 6 months, thereby conserving iron otherwise lost in menses (approximately 0.5 mg Fe day^{-1}). As iron is secreted in relatively low amounts in breast milk (approximately 0.24 mg Fe day^{-1}), net iron loss may be lower than in non-lactating women (Dewey 2004). Thus, breastfeeding may be protective against maternal iron deficiency. In addition, lactating women have been found to have greater serum ferritin concentrations than non-lactating women, indicating elevated iron stores in those who breastfed (Kalkwarf & Harrast 1998). This difference was not, however, observed in haemoglobin status.

Vitamins

The concentration of many vitamins in breast milk is dependent upon the vitamin status of the mother, with maternal deficiencies leading to deficiencies in the breastfeeding infant. Vitamins of particular concern in this respect include thiamine, riboflavin, vitamins B6 and B12 and vitamin A (Allen 1998; Allen 2005; Langley-Evans 2009). As a consequence, most European countries recommend an increased intake of all vitamins during lactation from NPNL levels (Table 3). Of the B vitamins, B12 has been the focus of the most research. Studies in B12-deficient lactating women demonstrate an association between the B12 status of the mother and her infant at 3 months post partum (Casterline *et al*. 1997). Vitamin A deficiency is a major public health problem in developing countries, and strategies such as high-dose supplementation of women post partum with vitamin A is an effective way of ensuring adequate supplies to the infant through breast milk (Sommer *et al*. 2002) and preventing deficiency. Vitamin D deficiency has gained a lot of interest in recent years, with the resurgence in the prevalence of rickets, particularly among South Asian immigrants to western Europe (Alfaham *et al*. 1995; Gillie 2004). Reduced sunlight exposure attributed to the prevalent use of sunscreen creams, sunlight avoidance or the wearing of traditional Muslim dress can contribute to vitamin D deficiency in pregnant and lactating mothers, which can lead to lowered breast milk concentrations (Seth *et al*. 2009). The transfer of maternal vitamin D to breast milk is poor; therefore, supplementation of the mother to raise breast milk vitamin D levels is inefficient. Direct supplementation of the infant can be an effective approach in the prevention of infantile rickets (Kovacs 2008).

Conclusion

Recommended intakes during lactation are often extrapolated from known secretion of the nutrient in milk with adjustments for bioavailability, so that differences between values can be partly ascribed to differences in methodological approaches and how these approaches are applied (Atkinson & Koletzko 2007). Recent research is providing new knowledge on the micronutrient requirements of lactating women. Identifying needs for research and improving understanding of the differences in values that have been derived by various committees and groups across Europe will enhance transparency and facilitate the application of reference values in policy-making decision and their translation into recommendations for lactating women. Given the wide variation in breastfeeding practices across Europe, making nutritional recommendations for lactating women is complex and challenging. It is crucial to first examine the cultural practices within and across European populations and to assess its relevance before making recommendations.

Care should be taken to avoid assumptions that providing the 'correct' information on nutritional requirements during lactation will lead women to make the 'right choices' in terms of their own nutrition and the patterns and practices of breastfeeding. This consumerist concept of decision making (knowledge in – behaviour out) is based on an illusion of linearity, and it ignores the complexities of decision making. In reality, decisions will be made based on macro-level (structural) factors such as socio-economic and political contexts, gender relationships and food availability along with micro-level factors such as local cultural practices, norms, lifestyles, attitudes and beliefs (Pelto 1987; Bilson & Dykes 2009).

When attempting to apply any future nutritional guidelines to this population group, attention should also be made to the social, cultural and economic factors that play a role in the eating behaviour and subsequent nutritional status of adolescents, particularly those who are pregnant or breastfeeding. In many western countries, adolescent childbearing is more prevalent among those with low levels of income and education than among their better-off peers (Singh *et al*. 2001). Poverty has been shown to be a significant factor that limits the ability of some childbearing adolescents to eat a healthy diet, even in those who aspire to it (Burchett & Seeley 2003).

Other socio-economic factors often experienced by such groups, including unemployment, poor housing, suboptimal mental and physical health, limited access to a wide variety of reasonably priced foods (Symon & Wrieden 2003), and an increased likelihood to smoke during and following pregnancy (Hamlyn *et al*. 2002) all contribute to difficulties in tackling behavioural change. Thus, achieving dietary change in this particularly vulnerable section of the population presents a major public health challenge.

Source of funding

The work report herein has been carried out within the EURRECA Network of Excellence (http://www.eurreca.org), which is financially supported by the Commission of the European Communities, specific Research Technology and Development (RTD) Programme Quality of Life and Management of Living Resources, within the Sixth Framework Programme (contract no. 036196).

Conflict of interest

This report does not necessarily reflect the Commission's views or its future policy in this area. The authors declare no conflict of interest.

References

Adair S.-R. (1993) Biological determinants of pregnancy weight gain: a longitudinal study of Filipino women. *American Journal of Clinical Nutrition* **57**, 365–372.

Alfaham M., Woodhead S., Pask G. & Davies D. (1995) Vitamin D deficiency: a concern in pregnant Asian women. *British Journal of Nutrition* **73**, 881–887.

Allen L.H. (1998) Zinc and micronutrient supplements for children. *American Journal of Clinical Nutrition* **68**, (Suppl.), 495S–498S.

Allen L.H. (2005) Multiple micronutrients in pregnancy and lactation: an overview. *American Journal of Clinical Nutrition* **81**, 1206S–1212S.

Almeida A.A., Lopes C.M., Silva A.M. & Barrado E. (2008) Trace elements in human milk: correlation with blood levels, inter-element correlations and changes in concentration during the first month of lactation. *Journal of Trace Elements in Medicine & Biology* **22**, 196–205.

Amir L.H. & Donath S.M. (2002) Does maternal smoking have a negative physiological effect on breastfeeding? The epidemiological evidence. *Birth* **29**, 112–123.

Anderson A.N. & Schioler V. (1982) Influence of breast-feeding pattern on pituitary–ovarian axis of women in an industrialized community. *American Journal of Obstetrics and Gynecology* **143**, 673–677.

Ashwell M., Lambert J.P., Alles M.S., Branca F., Bucchini L., Brzozowska A. *et al*. (2008) How we will produce the evidence-based EURRECA toolkit to support nutrition and food policy. *European Journal of Nutrition* **47** (Suppl 1), 2–16.

Atkinson S.A. & Koletzko B. (2007) Determining life-stage groups and extrapolating nutrient intake values (NIV). *Food and Nutrition Bulletin* **28** (Suppl.), 61–76.

Azizi F. & Smyth P. (2009) Breastfeeding and maternal and infant iodine nutrition. *Clinical Endocrinology* **70**, 803–809.

Baatenburg de Jong R., Bekhof J., Roorda R. & Zwart P. (2005) Severe nutritional vitamin deficiency in a breast-fed infant of a vegan mother. *European Journal of Pediatrics* **164**, 259–260.

Bas M., Karabudak E. & Kiziltan G. (2005) Vegetarianism and eating disorders: association between eating attitudes and other psychological factors among Turkish adolescents. *Appetite* **44**, 309–315.

Bezerra F.F., Mendonca L.M.C., Lobato E.C., O'Brien K.O. & Donangelo C.M. (2004) Bone mass is recovered from lactation to postweaning in adolescent mothers with low calcium intakes. *American Journal of Clinical Nutrition* **80**, 1322–1326.

Bhutta Z.A., Shekar M. & Ahmed T. (2008) Mainstreaming interventions in the health sector to address maternal and child under-nutrition. *Maternal and Child Nutrition* **4**, 1–4.

Bilson A. & Dykes F. (2009) A bio-cultural basis for protecting, promoting and supporting breastfeeding. In *Infant and Young Child Nutrition: Challenges to Implementing a Global Strategy* (eds F. Dykes & V. Hall Moran), pp. 32–42. Wiley-Blackwell: Oxford.

Burchett H. & Seeley A. (2003) *Good Enough to Eat? The Diet of Pregnant Teenagers*. Maternity Alliance/Food Commission: London.

Casterline J.E., Allen L.H. & Ruel M.T. (1997) Vitamin B-12 deficiency is very prevalent in lactating Guatemalan women and their infants at three months postpartum. *Journal of Nutrition* **127**, 1966–1972.

Cavelaars A.E.J.M., Kadvan A., Doets E.L., Tepsic J., Novakovic R., Dhonukshe-Rutten R. *et al*. (2010) NutriRecQuest: a web-based search engine on current micronutrient recommendations. *European Journal of Clinical Nutrition* **64**, S43–S47.

Cervera P. & Ngo J. (2001) Dietary guidelines for the breast-feeding woman. *Public Health Nutrition* **4**, 1357–1362.

Chantry C.J., Auinger P. & Byrd R.S. (2004) Lactation among adolescent mothers and subsequent bone mineral density. *Archives of Pediatric Adolescent Medicine* **158**, 650–656.

Cnattingius S., Bergström R., Lipworth L. & Kramer M.S. (1998) Prepregnancy weight and the risk of adverse pregnancy outcomes. *New England Journal of Medicine* **338**, 147–152.

Coufopoulos A.M. & Hackett A.F. (2009) Homeless mothers and their children: two generations at nutritional risk. In *Infant and Young Child Nutrition: Challenges to Implementing a Global Strategy* (eds F. Dykes & V. Hall Moran), pp. 146–162. Wiley-Blackwell: Oxford.

Davis R.E. (2001) The postpartum experience for Southeast Asian women in the United States. *Maternal and Child Nursing* **26**, 208–213.

Dewey K.G. (2004) Impact of breastfeeding on maternal nutritional status. *Advances in Experimental Medicine & Biology* **554**, 91–100.

Dewey K.G. & Cohen R.J. (2007) Does birth spacing affect maternal or child nutritional status? A systematic literature review. *Maternal & Child Nutrition* **3**, 151–173.

Delange F., Chanoine J.P., Abrassart C. & Bourdoux P. (1988) Topical iodine, breastfeeding, and neonatal hypothyroidism. *Archives of Disease in Childhood* **63**, 106–107.

Doets E.L., de Wit L.S., Dhonukshe-Rutten R.A., Cavelaars A.E., Raats M.M., Timotijevic L. *et al.* (2008) Current micronutrient recommendations in Europe: towards understanding their differences and similarities. *European Journal of Nutrition* **47** (Suppl 1), 17–40.

Domellof M., Lonnerdal B., Dewey K.G., Cohen R.J. & Hernell O. (2004) Iron, zinc, and copper concentrations in breast milk are independent of maternal mineral status. *American Journal of Clinical Nutrition* **79**, 111–115.

Dorea J.G. (2002) Iodine nutrition and breast feeding. *Journal of Trace Elements in Medicine & Biology* **16**, 207–220.

Dykes F. (2005) 'Supply' and 'Demand': breastfeeding as labour. *Social Science & Medicine* **60**, 2283–2293.

Dykes F. & Hall Moran V. (2006) Transmitted nutritional deprivation from mother to child: a socio-biological perspective. In *Maternal and Infant Nutrition & Nurture: Controversies and Challenges* (eds V. Hall Moran & F. Dykes), pp. 6–39. Quay Books: London.

Eltom A., Eltom M., Elnagar B., Elbagir M. & Gebre-Medhin M. (2000) Changes in iodine metabolism during late pregnancy and lactation: a longitudinal study among Sudanese women. *European Journal of Clinical Nutrition* **54**, 429–433.

Gibson R.S. (2005) *Principles of Nutritional Assessment*, 2nd edn, Oxford University Press: Oxford.

Gillie O. (2004) *Sunlight Robbery*. Health Research Forum Occasional Reports: No. 1 p. 20. Available at: http://www.healthresearchforum.org.uk

Goldade K., Nichter M., Nichter M., Adrian S., Tesler L. & Muramoto M. (2008) Breastfeeding and smoking among low-income women: results of a longitudinal qualitative study. *Birth* **35**, 230–240.

Graham S.M., Arvela O.M. & Wise G.A. (1992) Long-term neurologic consequences of nutritional vitamin B12 deficiency in infants. *Journal of Pediatrics* **121**, 710–714.

Greene-Finestone L.S., Campbell M.K., Evers S.E. & Gutmanis I.E. (2008) Attitudes and health behaviours of young adolescent omnivores and vegetarians: a school-based study. *Appetite* **51**, 104–110.

Hall Moran V. (2007) Nutritional status in pregnant adolescents: a systematic review of biochemical markers. *Maternal & Child Nutrition* **3**, 74–93.

Hambidge K.M. & Krebs N.F. (2007) Zinc deficiency: a special challenge. *Journal of Nutrition* **137**, 1101–1105.

Hamlyn B., Brooker S., Oleinikova K. & Wands S. (2002) *Infant Feeding 2000*. The Stationery Office: London.

Hess S.Y. & King J.C. (2009) Effects of maternal zinc supplementation on pregnancy and lactation outcomes. *Food & Nutrition Bulletin* **30**, S60–S78.

Hopkinson J.M., Schanler R.J., Fraley J.K. & Garza C. (1992) Milk production by mothers of premature infants: influence of cigarette smoking. *Pediatrics* **90**, 934–938.

Horta B.L., Kramer M.S. & Platt R.W. (2001) Maternal smoking and the risk of early weaning: a meta-analysis. *American Journal of Public Health* **91**, 304–307.

Institute of Medicine (2001) *Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc*. NAP: Washington DC.

Jackson M.J., Giugliano R., Giugliano L.G., Oliveira E.F., Shrimpton R. & Swainbank I.G. (1988) Stable isotope metabolic studies of zinc nutrition in slum-dwelling lactating women in the Amazon valley. *British Journal of Nutrition* **59**, 193–203.

Jarjou L.M., Prentice A., Sawo Y., Laskey M.A., Bennett J., Goldberg G.R. *et al.* (2006) Randomized, placebo-controlled, calcium supplementation study in pregnant Gambian women: effects on breast-milk calcium concentrations and infant birth weight, growth, and bone mineral accretion in the first year of life. *American Journal of Clinical Nutrition* **83**, 657–666.

Kalkwarf H.J. (1999) Hormonal and dietary regulation of changes in bone mineral density during lactation and after weaning in women. *Journal of Mammary Gland Biology & Neoplasia* **4**, 319–329.

Kalkwarf H.J. & Harrast S.D. (1998) Effects of calcium supplementation and lactation on iron status. *American Journal of Clinical Nutrition* **67**, 1244–1249.

Kalkwarf H.J. & Specker B.L. (2002) Bone mineral changes during pregnancy and lactation. *Endocrine* **17**, 49–53.

Karlsson C., Obrant K.J. & Karlsson M. (2001) Pregnancy and lactation confer reversible bone loss in humans. *Osteoporosis International* **12**, 828–834.

Kent J.C., Mitoulas L.R., Cregan M.D., Ramsay D.T., Doherty D.A. & Hartmann P.E. (2006) Volume and frequency of breastfeedings and fat content of breast milk throughout the day. *Pediatrics* **117**, e387–e395.

Kovacs C.S. (2008) Vitamin D in pregnancy and lactation: maternal, fetal, and neonatal outcomes from human and animal studies. *American Journal of Clinical Nutrition* **88**, 520S–528S.

Krebs N.F., Reidinger C.J., Hartley S., Robertson A.D. & Hambidge K.M. (1995) Zinc supplementation during lactation: effects on maternal status and milk zinc concentrations. *American Journal of Clinical Nutrition* **61**, 1030–1036.

Langley-Evans S. (2009) *Nutrition: A Lifespan Approach*. Wiley-Blackwell: Chichester.

Lonnerdal B. (2000) Regulation of mineral and trace elements in human milk: exogenous and endogenous factors. *Nutrition Reviews* **58**, 223–229.

Maia P.A., Figueiredo R.C.B., Anastácio A.S., Porto da Silveira C.L. & Donangelo C.M. (2007) Zinc and copper metabolism in pregnancy and lactation of adolescent women. *Nutrition* **23**, 248–253.

Merchant K., Martorell R. & Haas J. (1990) Maternal and fetal responses to the stresses of lactation concurrent with pregnancy and of short recuperative intervals. *American Journal of Clinical Nutrition* **52**, 280–288.

Moser P.B. & Reynolds R.D. (1983) Dietary zinc intake and zinc concentrations of plasma, erythrocytes, and breast milk in antepartum and postpartum lactating and nonlactating women: a longitudinal study. *American Journal of Clinical Nutrition* **38**, 101–108.

Moser-Veillon P.B. & Reynolds R.D. (1990) A longitudinal study of pyridoxine and zinc supplementation of lactating women. *American Journal of Clinical Nutrition* **52**, 135–141.

Neumark-Sztainer D., Story M., Resnick M.D. & Blum R.W. (1997) Adolescent vegetarians, a behavioural profile of a school-based population in Minnesota. *Archives of Pediatrics and Adolescent Medicine* **151**, 833–838.

Pavlovic M., Prentice A., Thorsdottir I., Wolfram G. & Branca F. (2007) Challenges in harmonising energy and nutrient recommendations in Europe. *Annals of Nutrition and Metabolism* **51**, 108–114.

Pebley A.R. & DaVanzo J. (1993) *Maternal Depletion and Child Survival in Guatemala and Malaysia*. RAND Health: Santa Monica, CA.

Pelto G. (1987) Cultural issues in maternal and child health and nutrition. *Social Science and Medicine* **25**, 553–559.

Perry C.L., McGuire M.T., Neumark-Sztainer D. & Story M. (2001) Characteristics of vegetarian adolescents in a multiethnic urban population. *Journal Adolescent Health* **29**, 406–416.

Picciano M.F. (2003) Pregnancy and lactation: physiological adjustments, nutritional requirements and the role of dietary supplements. *Journal of Nutrition* **133**, 1997S–2002S.

Pijls L., Ashwell M. & Lambert J. (2009) EURRECA – a network of excellence to align European micronutrient recommendations. *Food Chemistry* **113**, 748–753.

Rah J.H., Christian P., Shamim A.A., Arju U.T., Labrique A.B. & Rashid M. (2008) Pregnancy and lactation hinder growth and nutritional status of adolescent girls in rural Bangladesh. *Journal of Nutrition* **138**, 1505–1511.

Rah J.H., Shamim A.A., Arju U.T., Labrique A.B., Klemm R.D.W., Rashid M. & Christian P. (2010) Difference in ponderal growth and body composition among pregnant vs. never-pregnant adolescents varies by birth outcomes. *Maternal & Child Nutrition*.

Ritchie L.D., Fung E.B., Halloran B.P., Turnlund J.R., Van L., Cann C.E. & King J.C. (1998) A longitudinal study of calcium homeostasis during human pregnancy and lactation and after resumption of menses. *American Journal of Clinical Nutrition* **67**, 693–701.

Rogol A.D., Clark P.A. & Roemmich J.N. (2000) Growth and pubertal development in children and adolescents: effects of diet and physical activity. *American Journal of Clinical Nutrition* **72**, 521S–528S.

Rozen G.S., Rennert G., Dodiuk-Gad R.P., Rennert H.S., Ish-Shalom N., Diab G. *et al*. (2003) Calcium supplementation provides an extended window of opportunity for bone mass accretion after menarche. *American Journal of Clinical Nutrition* **78**, 993–998.

Scavenius M., vHulsel L., Meijer J., Wendte H. & Gurgel R. (2007) In practice, the theory is different: a processual analysis of breastfeeding in north east Brazil. *Social Science and Medicine* **64**, 676–688.

Scholl T.O., Hediger M.L. & Ances I.G. (1990) Maternal growth during pregnancy and decreased infant birth weight. *American Journal of Clinical Nutrition* **51**, 790–793.

Scholl T.O., Hediger M.L., Cronk C.E. & Schall J.I. (1993) Maternal growth during pregnancy and lactation. *Hormone Research* **39** (Suppl. 3), 59–67.

Sellen D.W. (2001) Weaning, complementary feeding, and maternal decision making in a rural East African pastoral population. *Journal of Human Lactation* **17**, 233–244.

Seth A., Marwaha R.K., Singla B., Aneja S., Mehrotra P., Sastry A. *et al*. (2009) Vitamin D nutritional status of exclusively breast fed infants and their mothers. *Journal of Pediatric Endocrinology* **22**, 241–246.

Sian L., Krebs N.F., Westcott J.E., Fengliang L., Tong L., Miller L.V. *et al*. (2002) Zinc homeostasis during lactation in a population with a low zinc intake. *American Journal of Clinical Nutrition* **75**, 99–103.

Sing S., Darroch J.E. & Frost J.J. (2001) Socioeconomic disadvantage and adolescent women's sexual and reproductive behavior: the case of five developed countries. *Family Planning Perspectives* **33**, 251–258 & 289.

Sommer A., Davidson F.R. & Annecy A. (2002) Assessment and control of vitamin A deficiency: the Annecy Accords. *Journal of Nutrition* **132** (Suppl), 2845S–2850S.

Specker B.L., Black A., Allen L. & Morrow F. (1990) Vitamin B12 low milk concentrations are related to low serum, concentrations in vegetarian women and to methylmalonic aciduria in their infants. *American Journal of Clinical Nutrition* **52**, 1073–1076.

Spiro A. (2006) Gujarati women and infant feeding decisions. In *Maternal and Infant Nutrition and Nurture: Controversies and Challenges* (eds V. Hall Moran & F. Dykes), pp. 232–249. Quay Books: London.

Stapleton H. & Keenan J. (2009) Bodies in the making: reflections on women's consumption practices in pregnancy. In *Infant and Young Child Nutrition: Challenges to Implementing a Global Strategy* (eds F. Dykes & V. Hall Moran), pp. 119–145. Wiley-Blackwell: Oxford.

Symon A.G. & Wrieden W.L. (2003) A qualitative study of pregnant teenagers' perceptions of the acceptability of a nutritional education intervention. *Midwifery* **19**, 140–147.

Villamor E. & Cnattingius S. (2006) Interpregnancy weight change and risk of adverse pregnancy outcomes: a population-based study. *The Lancet* **368**, 1164–1170.

Vio F., Salazar G. & Infante C. (1991) Smoking during pregnancy and lactation and its effects on breast-milk volume. *American Journal of Clinical Nutrition* **54**, 1011–1016.

Wagnon J., Cagnard B., Bridoux-Henno L., Tourtelier Y., Grall J.Y. & Dabadie A. (2005) Breastfeeding and vegan diet. *Journal de Gynecologie, Obstetrique et Biologie de la Reproduction* **34**, 610–612.

Wambach K. & Riordan J. (2010) The cultural context of breastfeeding. In *Breastfeeding and Human Lactation* (eds J. Riordan & K. Wambach), pp. 799–816. Jones and Bartlett Publishers: London.

Weiss R., Fogelman Y. & Bennett M. (2004) Severe vitaminB12 deficiency in an infant associated with a maternal deficiency and strict vegetarian diet. *Journal of Pediatric Hematology and Oncology* **26**, 270–271.

WHO (1998) *Complementary Feeding of Young Children in Developing Countries: Review of the Current Scientific Knowledge*. WHO: Geneva.

WHO (2000) *Collaborative Study Team on the Role of Breastfeeding on the Prevention and of Infant Mortality*. WHO: Geneva.

WHO (2003) *Global Strategy for Infant and Young Child Feeding*. Geneva: WHO.

WHO (2007) *Assessment of Iodine Deficiency Disorders and Monitoring their Elimination. A Guide for Program Managers*, 3rd edn. WHO: Geneva.

WHO/Food and Agriculture Organization of the United Nations (FAO) (2004) *Vitamin and Mineral Requirements in Human Nutrition*, 2nd edn. WHO/FAO: Geneva.

Widstrom A.M., Werner S., Matthiesen A.S., Svensson K. & Uvnas-Moberg K. (1991) Somatostatin levels in plasma in non-smoking and smoking breastfeeding women. *Acta Paediatrica Scandinavica* **80**, 13–21.

Worsley A. & Skrzypiec G. (1998) Teenage vegetarianism: prevalence, social and cognitive contexts. *Appetite* **30**, 151–170.

Zimmermann M. & Delange F. (2004) Iodine supplementation of pregnant women in Europe: a review and recommendations. *European Journal of Clinical Nutrition* **58**, 979–984.