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Current micronutrient recommendations in Europe: towards understanding their differences and similarities

■ **Abstract** *Background* Nowadays most countries in Europe have established their own nutrient recommendations to assess the

adequacy of dietary intakes and to plan desirable dietary intakes. As yet there is no standard approach for deriving nutrient recommen-

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dations, they may vary from country to country. This results in different national recommendations causing confusion for policy-makers, health professionals, industry, and consumers within Europe. EURRECA (EUROpean micronutrient RECommendations Aligned) is a network of excellence funded by the European Commission (EC), and established to identify and address the problem of differences between countries in micronutrient recommendations. The objective of this paper is to give an overview of the available micronutrient recommendations in Europe, and to provide information on their origin, concepts and definitions. Furthermore this paper aims to illustrate the diversity in European recommendations on vitamin A and vitamin D, and to explore differences and commonalities in approaches that could possibly explain variations observed.

Methods A questionnaire was developed to get information on the process of establishing micronutrient recommendations. These questionnaires were sent to key informants in the field of micronutrient recommendations to cover all European countries/regions. Also the latest reports on nutrient recommendations in Europe were collected. Standardisation procedures were defined to

enable comparison of the recommendations. Recommendations for vitamin A and vitamin D were compared per sex at the ages 3, 9 months and 5, 10, 15, 25, 50 and 70 years. Information extracted from the questionnaires and reports was compared focusing on: (1) The concept of recommendation (recommended daily allowance (RDA), adequate intake (AI) or acceptable range), (2) The year of publication of the report (proxy for available evidence), (3) Population groups defined, (4) Other methodological issues such as selected criteria of adequacy, the type of evidence used, and assumptions made.

Results Twenty-two countries, the World Health Organization (WHO)/the Food and Agriculture Organization of the United Nations (FAO) and the EC have their own reports on nutrient recommendations. Thirteen countries based their micronutrient recommendations on those from other countries or organisations. Five countries, WHO/FAO and the EC defined their own recommendations. The DACH-countries (Germany, Austria and Switzerland) as well as the Nordic countries (Norway, Sweden, Finland, Denmark and Iceland) cooperated in setting recommendations. Greece and Portugal use the EC and the WHO/FAO recommendations,

respectively and Slovenia adopted the recommendations from the DACH-countries. Rather than by concepts, definitions, and defined population groups, variability appears to emerge from differences in criteria for adequacy, assumptions made and type of evidence used to establish micronutrient recommendations.

Discussion The large variation in current micronutrient recommendations for population groups as illustrated for vitamin A and vitamin D strengthens the need for guidance on setting evidence based, up-to-date European recommendations. Differences in endpoints, type of evidence used to set recommendations, experts' opinions and assumptions are all likely to contribute to the identified variation. So far, background information was not sufficient transparent to disentangle the relative contribution of these different aspects.

Conclusion EURRECA has an excellent opportunity to develop tools to improve transparency on the approaches used in setting micronutrient recommendations, including the selection of criteria for adequacy, weighing of evidence, and interpretation of data.

■ **Key words** micronutrients – recommendations – nutrient requirements – EURRECA

Background

Most likely, the first true dietary recommendations were proposed by Dr. Edward Smith in 1862 in response to a request from the British Privy Council. The council wanted to determine the least cost for which enough food could be purchased to prevent starvation and associated diseases among the population that was unemployed as the result of the economic depression of the time. Since then, many other nutrient recommendations have been proposed that were used for the planning of food supplies and ration scales during times of war and food shortages,

focussing merely on the prevention of deficiencies [23]. Due to the continuously increasing knowledge on the physiological role of nutrients, and the health consequences of micronutrient deficient diets, the concept of dietary and nutrient recommendations still receives much attention [37]. Nowadays most countries in Europe have established their own nutrient recommendations to assess the adequacy of dietary intakes and to plan desirable dietary intakes both at the individual and population level [1, 4–8, 11–16, 18, 19, 22, 24–31, 34, 36, 39, 41–45, 50, 53]. These recommendations serve as a basis for national or regional nutrition policies, nutritional education programs, food regulations and action programs.

Table 1 Paradigm of nutrition science: classical and extensions of the twenty-first century

+	Classical	Twenty-first century
Scientific domain	<ul style="list-style-type: none"> • Essential nutrients (± 50) • Biological effects • Adequate intake via food 	<ul style="list-style-type: none"> • Essential nutrients and bio-active food components • Biological effects • Adequate intake via food, supplements and “functional foods”
Basis for nutrient recommendation (criteria for adequacy)	<ul style="list-style-type: none"> • Prevention of deficiency diseases 	<ul style="list-style-type: none"> • Avoid toxic levels • Prevention of deficiency diseases • Prevention of chronic diseases (optimal health)
Variables taken into account for recommendation (assumptions)	<ul style="list-style-type: none"> • Age, sex, physical activity, body weight • Made up for groups 	<ul style="list-style-type: none"> • Age, sex, physical activity, body weight • Ethnicity • Heredity • Genetic predisposition for disease • Made up for groups and individuals • Food patterns • Lifestyle and environment
Scientific Base (type of evidence)	<ul style="list-style-type: none"> • Clinical “depletion-repletion” model 	<ul style="list-style-type: none"> • Epidemiology: Meta-analyses and RCT provide best funded evidence

Based on IOM [35] and van Staveren [46]

In 1993, the European Commission (EC) defined population reference intakes (PRIs) to be used for food labelling in Europe [6].

The approach to establish nutrient recommendations has changed over the course of time. The classical paradigm focused on an adequate intake of nutrients via food to prevent deficiencies based on clinical trials. In 1994, the Food and Nutrition Board of the Institute of Medicine (IOM) introduced dietary reference intakes (DRIs) for the United States of America and Canada including many aspects of the conceptual framework from the report published in the United Kingdom [36]. These DRIs represented a paradigm shift in the way nutrient recommendations were established and used by practitioners, educators, and researchers. Besides the prevention of deficiencies, DRIs were intended to help individuals optimize their health, prevent disease, and avoid consuming too much of a nutrient. Furthermore the IOM paradigm placed greater emphasis on the distribution of nutrient requirements within a population, rather than on a single value and they quantified the relationship between a nutrient and the risk of disease based on scientific evidence [35].

In Table 1 the classical paradigm and the new paradigm as presented by the IOM are shown.

The DRIs included four nutrient-based reference values: estimated average requirement (EAR), the recommended dietary allowance (RDA), the adequate intake (AI) and the tolerable upper intake level (UL). The EAR is defined as the average daily nutrient intake level that is estimated to meet the requirements of half of the healthy individuals in a particular life-stage and gender group. The RDA represents the average daily dietary nutrient intake level that is sufficient to meet the nutrient requirements of nearly

all (97–98%) healthy individuals in a particular life-stage and gender group. When an RDA cannot be determined, an AI is estimated which is the recommended average daily intake level based on observed or experimentally determined approximations or estimates of nutrient intake by a group (or groups) of apparently healthy people that are assumed to be adequate. The UL is outside the scope of this paper [35].

Pavlovic et al. [37], King et al. [21] and Prentice et al. [38] compared a selection of European nutrient recommendations to provide an overview of existing differences in terminologies and reference values. The countries/organisations included were: the Nordic countries (Norway, Sweden, Denmark, Finland and Iceland), the DACH-countries (Germany, Austria and Switzerland), the United Kingdom, the Netherlands, Italy, World Health Organization (WHO)/Food and Agricultural Organization of the United Nations (FAO), and EC. From these comparisons, it appeared that often nutrient recommendations have been established involving small and select committees of experts. As yet there is no standard approach for deriving nutrient recommendations, they vary from country to country. This occurs even for well-defined population groups that are assumed to have the same physiological requirements. Given the lack of standardized methodologies, some nations/organisations provide, for example, one single recommendation for all adults grouped together, while others provide recommendations separately for males and females [21].

Besides such differences in methodologies, national recommendations are reviewed at different times so they may not always be based on the same most up-to-date scientific information. Furthermore, cultural and regional factors may affect the weighing

of evidence and the decision process. This results in different national recommendations causing confusion for policy-makers, health professionals, industry, and consumers within Europe.

Harmonisation will improve the objectivity and transparency of values that are derived by various national, regional and international groups. Where harmonisation is not possible, transparency is needed on the approaches to establish recommendations. This will improve understanding and explanation of potential differences between recommendations and simplifies their application in policy making.

■ EURRECA Network of Excellence (www.eurreca.org)

EURRECA (EUROpean micronutrient RECommenda-tions Aligned) is a network of excellence funded by the EC and established to identify and address the problem of differences between countries in micro-nutrient recommendations. It is originally made up of 34 partners based in 17 countries, drawn not only from nutrition science but also from industry, consumer groups, national nutrition societies and health professions. Based on previous experiences of the University of the United Nations (UNU) [20] and the International Life Sciences Institute (ILSI) in the WHO South-East Asia Region [17], EURRECA works towards a general framework including harmonized approaches, methods and key terms to be used for the development of micronutrient recommendations. This general framework will supply a basis for the use of micronutrient recommendations across countries/regions for establishing public and clinical health objectives, food and nutrition policies, and for addressing trade and regulatory issues [21].

Further details on the network can be found in the article by Ashwell et al. [2].

■ Aims and objectives

One of the research activities within EURRECA (Research Activity 1.4: Current Recommendations for population groups) aims to collate, compare and critically evaluate existing micronutrient recommendations for all population groups set by European countries/organisations. The objective of this paper is to give an overview of the availability of nutrient recommendations in Europe and to provide information on the origin, concepts and definitions used, and population groups defined. Furthermore this paper shows the diversity in European recommendations on vitamin A and vitamin D, and aims to explore differences and commonalities in approaches that could possibly explain variations observed. These two

nutrients were selected because vitamin D already had some attention in earlier stages of the EURRECA network and vitamin A was selected because much work on this nutrient was already done by the authors. In the near future other nutrients will be studied and more in depth comparisons will be made. The results of these explorations will be used to identify gaps and opportunities on which subsequent activities within EURRECA can build.

Methods

■ Data collation

To obtain a comprehensive overview of currently used concepts and methods in European countries, a questionnaire was developed by the Division of Human Nutrition of Wageningen University and Research Centre (WUR) in the Netherlands in cooperation with the Food, Consumer Behaviour and Health Research Centre of the University of Surrey in the United Kingdom. Questions addressed three stages of the process of micronutrient policy development. The first stage concerned the approach for setting micronutrient recommendations, while the other two investigated the process from micronutrient recommendations to nutrition policies and options and applications for public health policy. Only the first stage will be reported in this overview.

The questionnaire included open-ended questions on the process of setting up recommendations and close-ended questions on the people involved in the process and the type of evidence used. Each of the 11 questions addressed the nutrients considered to be most relevant to public health: vitamins A, D, E, C, thiamin (B1), riboflavin (B2), niacin (B3), pyridoxine (B6), cobalamin (B12), folic acid (B11), sodium, potassium, calcium, magnesium, iron, zinc, copper, phosphorus, selenium, and iodine.

Questionnaires were distributed among seven EURRECA partners, (University of Oslo (Norway), National Institute of Public Health (Czech Republic), Institute for Medical Research (Serbia), Warsaw Agricultural University (Poland), University College Cork (Ireland), WHO Regional Office for Europe, and WUR, in August 2007. Subsequently, these partners sent the questionnaires to key informants in the field of micronutrient recommendations to cover all European countries/regions. Key-informants were asked to fill out the questionnaire, if necessary with help of others, and return it in September 2007 also providing the latest report(s) on nutrient recommendations. After the deadline had expired, the key-informants of the missing countries were followed up to increase response rate.

Table 2 List of European countries with published micronutrient recommendations and their recommendation report's origin

Country/organisation	Source		Origin				Remark
	Year	Ref no.	Own	Shared	Adopted	No info. provided	
Albania	2005	[4]			×		Adopted from literature, especially from the Linus Pauling Institute (http://lpi.oregonstate.edu/)
Austria	2000	[13]		×			Shared document with Germany and Switzerland
Belgium ^a	2006	[16]	×		×		Based on WHO [48], EC (1990) [no ref. provided], European countries that are geographically and culturally related to Belgium, e.g. UK [36], Netherlands [33] and France [25]
Federation of Bosnia and Herzegovina ^b	2000	[5]			×		Adopted from unknown source(s)
Republika of Srpska ^b	2005	[39]	×		×		Based on WHO [40, 48–51], WHO/FAO [9] and IOM [10]
Bulgaria	2005	[27]	×		×		Based on IOM [10] and WHO [2]
Croatia	2004	[7]	×		×		Aligned with EU legislation
Czech Republic	Not published				×		Adopted from Nutrition Society [no ref. provided] and EC [6]
Denmark	2004	[34]		×			Shared document with Finland, Iceland, Norway, Sweden
Estonia	2006	[45]	×		×		Based on Nordic Council of Ministers [34]
Finland	2004	[34]	×	×			Shared document (Denmark, Iceland, Norway, Sweden) is translated into own country specific document
	2005	[31]					
France	2001	[25]	×				
Germany	2000	[13]		×			Shared document with Austria and Switzerland
Greece	1993	[6]			×		Adopted from EC [6]
Hungary	2005	[1]	×		×		Based on EC [6] and IOM [10]
Iceland	2004	[34]	×	×			Shared document (Denmark, Finland, Norway, Sweden) is translated into own country specific document; Own recommendations for vitamin D and calcium
	2006	[43]					
Ireland	1999	[12]	×		×		Adopted from EC [6] and UK [36]; Own recommendations for folate, iron, calcium, vitamin C
Italy	1996	[42]	×		×		Based on NRC [32] and EC [6]
Latvia	2001	[22]	×				
Lithuania	1999	[24]	×				
Netherlands	1992	[11]	×				
	2000	[14]					
	2003	[15]					
Norway	2004	[34]	×	×			Shared document (Denmark, Finland, Sweden, Iceland) is translated into own country specific document
	2005	[8]					
Poland	1996	[53]	×		×		Based on NRC [10], UK [36] and EC [6]
Portugal	2004	[50]			×		Adopted from WHO/FAO (2004) [50]
Romania	1990	[18]				×	
Russian Federation ^a	1991	[29]				×	Valid from 1991, publication year 1992
Serbia	1994	[41]	×		×		Adopted from unknown source(s)
Slovakia	1997	[19]	×		×		Adopted from unknown source(s)
Slovenia	2004	[26]			×		Adopted from Austria, Germany, Switzerland (2004) [13]
Spain ^a	2007	[30]	×		×		Adopted from unknown sources. Published as a book chapter
Sweden	2004	[34]	×	×			Shared document (Denmark, Finland, Iceland, Norway) is translated into own country specific document
	2005	[44]					
Switzerland	2000	[13]		×			Shared document with Austria and Germany; Own recommendations for Iodine
The former YR Macedonia	2001	[28]	×		×		Based on recommendations of Former Republics of Yugoslavia (based on WHO) and UK [no ref. provided]
United Kingdom	1991	[36]	×				
EC ^a	1993	[6]	×				
WHO/FAO ^a	2004	[50]	×				

Based on questionnaire primarily and recommendation report (when available) secondarily. Montenegro is excluded from the list because no questionnaire nor recommendation report was available for the author

^aBased on recommendation report only

^bEntities of Bosnia and Herzegovina

The former YR Macedonia = The former Yugoslav Republic of Macedonia; EC European Commission, WHO/FAO World Health Organization/Food and Agricultural Organization

Own country specific recommendations developed

Shared recommendations set by one collaborative committee representing different countries

Adopted recommendations borrowed from other nation/organization

Table 3 Description of currently available recommendations across Europe*

Source		Type/concept used	Equivalent to DRI/RDA/AI/Acceptable range	Description	Micronutrients
Country	Year Ref no.				
Albania	2005 [4]	RDA ^Q	Insufficient info provided	Recommended Dietary Allowance, which is based on the biological needs for the normal individual of 23 to 55 years	All
Belgium	2006 [16]	Recommended Dietary Allowance Recommended daily amount of absorption Acceptable daily amount of absorption	DRI RDA AI/Acceptable range	General term for the set of recommendations AR + 2SD, covering at least 97.5% of the population Recommended daily absorption amount of adequate intake is the lowest level of intake, estimated, and covers practically the entire population: the adequate intake. This figure will be higher than the RDA in most cases	All, except for vitamin D, sodium, potassium, iodine, copper Vitamin D, sodium, potassium, iodine, copper
Bulgaria	2005 [27]	DRI RDA AI	DRI RDA AI	General term for the set of recommendations Recommended Dietary Allowance is the AR + 2SD Adequate Intake is the estimation of the lowest intake level that seems sufficient for almost all people in a group	All, except for calcium, sodium, potassium Calcium, sodium, potassium
DACH countries	2000 [13]	Reference value for nutrient intake Recommended Nutrient Intake (RNI) Estimated value for adequate intake	DRI RDA AI/Acceptable range	General term for the set of recommendations AR + 2SD. These amounts should cover the needs of nearly 98% of the population and protect against deficiency related damage to health Estimated values for Adequate Intake, using data that, though supported by experiment and mostly derived from intakes of healthy, well nourished groups, have not been adequately validated	All, except for vitamin E, sodium, potassium, copper, selenium Vitamin E, sodium, potassium, copper, selenium
Estonia	2006 [45]	Recommended Intake (RI)	Insufficient info provided	Average daily intake over time, for use in planning diets for groups	All
France	2001 [25]	ANC PRI AI	DRI RDA AI	General term for the set of recommendations Recommended Dietary Intake is the AR + 2SD The adequate intakes have been set on the basis of the observed deficiency thresholds, from the state of the reserves and sometimes from the quantities usually consumed with no apparent impact on health	All, except for vitamin D, vitamin E, folate, riboflavin, thiamin, selenium, iodine Vitamin D, vitamin E, folate, riboflavin, thiamin, selenium, iodine
Hungary	2005 [1]	safe intake	na	Recommendation for 100% of the population, based on EAR	All, except for sodium
Ireland	1999 [12]	maximum intake Recommended Dietary Allowance (RDA) Recommended Daily Allowance (RDA) RDA (LARN)	na DRI RDA RDA	No information provided General term for the set of recommendations AR + 2SD	Sodium All
Italy	1996 [42]	Acceptable intake range ^Q Recommended average Daily Intake	Acceptable range insufficient info provided	Recommended Daily Intake is the AR + 2SD. This procedure guarantees the coverage of the basic nutritional needs of over 97% of the population no information provided	All, except for vitamin E, sodium, magnesium Vitamin E, sodium, magnesium
Latvia	2001 [22]	Recommended average Daily Intake	insufficient info provided	no information provided	All

Table 3 Continued*

Source		Type/concept used	Equivalent to DRI/RDA/AI/ Acceptable range	Description	Micronutrients
Country	Year Ref no.				
Lithuania	1999 [24]	RDA	RDA	AR + 2SD ^Q	All
Netherlands	1992 [11]	RDA (ADH)	DRI	General term for the set of recommendations	All
	2000 [14]				
	2003 [15]	RDA	RDA	Recommended Amount is the EAR + 2SD	Vitamin B6, vitamin B12, folate, thiamin, riboflavin, niacin
		AI	AI	Adequate Intake is an estimation of the lowest intake level that seems sufficient for almost all people in a group; defined in case the EAR is not known	All, except for magnesium, zinc, copper, phosphorus, selenium
		Adequate area of Intake	Acceptable range	Adequate Intake is an estimation of the lowest intake level that seems sufficient for almost all people in a group; defined in case the EAR is not known	Magnesium, zinc, copper, phosphorus, selenium
Nordic countries	2004 [34]	Recommended Intake (RI)	RDA	The amount of a nutrient that according to present knowledge can meet the known requirement and the maintain good nutritional status among practically all healthy individuals	All
Poland	1996 [53]	Safe intake level (s.l.)	RDA	Safe intake level is the amount of nutrient which is adequate to meet nutritional needs of 97.5% of all individual in a group: mean for group + 2SD: used for assessment	All, except for copper, sodium, potassium
		Recommended intake (r.i.)	na	Recommended intake is the amount of nutrient which is adequate to meet nutritional needs of 100% of all individual in a group and is dedicated to planning diets for groups	All, except for copper, sodium, potassium
		Recommended safe level (r.s.l.)	Acceptable range	Range based on observations that individual consumption within this limits appears satisfactory and neither deficiency nor signs of excess are seen, used when there is no data to establish recommendation as one number	Copper
		Minimal intake (m.i.)	AI/Acceptable range	ranges and values considering the necessity of reducing salt consumption	Sodium, potassium
Romania	1990 [18]	Recommended amounts RDA ^Q	DRI insufficient info provided	General term for the set of recommendations Physiological needs / Recommended amounts	All All
Russian Federation	1991 [29]	Recommended level of intake	Insufficient info provided	Criterion for assessment of nutritional adequacy	All, except for copper
		Safe level of intake	AI	Where a recommended level of intake is not possible to establish	Copper
Serbia	1994 [41]	Recommended dietary allowance (DP)	RDA ^{PC}	DP = daily needs	All
Slovakia	1997 [19]	RDA (OVD)	Insufficient info provided	Recommended Dietary Allowance for population groups, intended for production, consumption and as the ground for diets and food based dietary guidelines	All
Spain	2007 [30]	no information provided	Insufficient info provided	no information provided	No information provided
The former YR Macedonia	2001 [28]	Recommended Daily Allowance (RDA)	Insufficient info provided	insufficient info provided	All (ranges for copper, selenium, sodium, potassium)

Table 3 Continued*

Source			Type/concept used	Equivalent to DRI/RDA/AI/Acceptable range	Description	Micronutrients
Country	Year	Ref no.				
United Kingdom	1991	[36]	Dietary reference Value (DRV)	DRI	General term for the set of recommendations EAR + 2SD	All
			Recommended Nutrient Intake (RNI)	RDA		
EC	1993	[6]	Safe intake	AI/acceptable range	A level or range of intakes at which there is no risk on deficiency and below a level where there is a risk of undesirable effects	Copper, iodine, potassium, selenium, sodium
			PRI	RDA	Population Reference Intake is the AR + 2SD, covering at least 97.5% of the population	All, except for vitamin D, sodium, magnesium
WHO/FAO	2004	[50]	Acceptable range	Acceptable range	Acceptable Range of Intake is there where data are inadequate for making recommendations, and based on observations that individual consumptions within these limits appears satisfactory in that neither deficiency nor signs of excess are seen	Vitamin D, sodium, magnesium
			Recommended Nutrient Intake (RNI)	RDA	Recommended Nutrient Intake is EAR + 2SD, which meets the nutrient requirements of almost all (97.5%) apparently healthy individuals in an age- and sex-specific population level of intake that prevents clinical signs of deficiency and allows normal growth, but is does not protect vitamin A status during prolonged periods of infection or other deceases	All, except for vitamin E, vitamin A
			Recommended safe intake level	AI	Best estimate of requirement, because data was not strong enough to formulate recommendations	Vitamin A
			Acceptable intake	AI		Vitamin E

*Based on recommendation report. Croatia, Federation of Bosnia and Herzegovina and Republika of Srpska (entities of Bosnia and Herzegovina) and Montenegro are excluded from the table because no recommendation report was available for the author and information could not be extracted from the questionnaire. The Czech Republic was excluded due to lack of published source
DACH countries = Austria, Germany, Switzerland; Nordic countries = Denmark, Finland, Iceland, Norway, Sweden; The former YR Macedonia = The former Yugoslav Republic of Macedonia, EC European Commission, WHO/FAO World Health Organization/Food and Agricultural Organization
Footnotes in local language were not taken into account

^Q based on questionnaire only

^{PC} personal communication

DRI Dietary Reference Intake = General term for the set of recommendations [35]

RDA Recommended Dietary Allowance = (Estimated) Average Requirement + 2 standard deviation [(E)AR + 2SD] = Daily dietary intake level of a nutrient considered sufficient to meet the requirements of 97–98% of healthy individuals in each life-stage and gender group [35]

AI Adequate Intake = The derived intake by a defined population group that appears to sustain health, used when there are insufficient primary data to establish a statistical distribution of individual requirements [35]

na not applicable = a concept derived from the RDA

All vitamins A, D, E, C, B1, B2, B3, B6, B12, folic acid, sodium, potassium, calcium, magnesium, iron, zinc, copper, phosphorus, selenium, iodine (if applicable)

■ Data extraction

Both the completed questionnaires and the recommendation reports were used to extract micronutrient recommendations, information on their origin, the approach used for estimating them, definitions and concepts, scientific evidence used, and population groups considered. Any unclear information given in the returned documents was re-checked with the key-informants to be sure that correct information was extracted.

■ Comparison of recommendations for vitamin A and vitamin D

As micronutrient recommendations usually consist of values, ranges, multiple values applying to one population group, (for example values for different activity levels), or additional amounts for sub groups (for example pregnant females), standardisation procedures were defined to enable comparison of the recommendations. In case of multiple recommendations

Table 4 Characteristics of population groups as observed in Dietary Reference Intake documents of different European countries*

Source	Age			Upper age group (years)	Other characteristics			
	Year	Ref no.	Age span					
Albania ^a	2005	[4]	All ages	0-6, 7-12	Age groups 1-18 years: 1-3, 4-8, 9-13, 14-18 (m/f)	Age groups adults (years): ≥19 (m/f)	Upper age group (years): ≥19	P and L: age ≤ 18 years, ≥19 years P, L
Belgium ^b	2006	[16]	All ages	0-12	1-3, 4-6, 7-10, 11-14, 15-18 (m/f)	19-59 (m/f), ≥60 (m/f)	≥60	P, L
Bulgaria ^c	2000	[27]	All ages	0-5, 6-12	1-2, 3-6, 7-9, 10-13 (m/f), 14-18 (m/f)	19-29 (m/f), 30-59 (m/f), 60-75 (m/f), ≥76 (m/f)	≥76	P and L: age ≤ 18 years, ≥19 years
DACH countries ^d	2000	[13]	All ages	0-3, 4-12	1-3, 4-6, 7-9, 10-12, 13-14 (m/f), 15-18 (m/f)	19-24 (m/f), 25-50 (m/f), 51-64 (m/f), ≥65 (m/f)	≥65	P: ≥4 months, L
Estonia	2006	[45]	≥6 months	6-12	1, 2-5, 6-9, 10-13 (m/f), 14-17 (m/f)	18-30 (m/f), 31-60 (m/f), 61-74 (m/f), ≥75 (m/f)	≥75	P, L
France ^e	2001	[25]	All ages	0-12	1-3, 4-6, 7-9, 10-12, 13-15 (m/f), 16-19 (m/f)	20-74 (m/f), ≥75 (m/f)	≥75	P, L
Hungary	2005	[1]	All ages	0-6, 7-24	2-3, 4-6, 7-10, 11-14 (m/f), 15-18 (m/f)	19-30 (m/f), 31-60 (m/f), ≥61	≥61	P, L
Ireland	1999	[12]	All ages	0-3, 4-6, 7-9, 10-12	1-3, 4-6, 7-10, 11-14 (m/f), 15-17 (m/f)	18-64 (m/f), ≥65 (m/f)	≥65	P: second half, L: first 6 months
Italy ^f	1996	[42]	≥6 months	6-12	1-3, 4-6, 7-10, 11-14, 15-17 (m/f)	18-29 (m/f), 30-59 (m), 30-49 (f), ≥60 (m), ≥50 (f)	≥60 (m), ≥50 (f)	P, L
Latvia ^g	2001	[22]	All ages	0-6, 7-12	1-3, 4-6, 7-10, 11-14, 15-18 (m/f)	≥19	≥19	P, L
Lithuania	1999	[24]	≤64 years	0-3, 4-6, 7-9, 10-12	1-3, 4-6, 7-10, 11-14 (m/f), 15-18 (m/f)	19-34 (m/f), 35-49 (m/f), 50-64 (m/f)	50-64	P and L: 4 PA levels and 2 body weights. PA: 4 levels (m/f) and 2 body weights (m), 2 body weights (f)
Netherlands ^h	1992 2000 2003	[11] [14] [15]	All ages	0-5, 6-12	1-3 (m/f), 4-6 (m/f), 7-9 (m/f), 10-12 (m/f), 13-15 (m/f), 16-18 (m/f)	19-21 (m/f), 22-49 (m/f), 50-64 (m/f), ≥65 (m/f)	≥65	P, L
Nordic countries ⁱ	2004	[34]	All ages	0-5, 6-12	1, 2-5, 6-9, 10-13 (m/f), 14-17 (m/f)	18-30 (m/f), 31-60 (m/f), 61-74 (m/f), ≥75 (m/f)	≥75	P, L
Poland	1996	[53]	All ages	0-5, 6-12	1-3, 4-6, 7-9, 10-12 (m/f), 13-15 (m/f), 16-18 (m/f)	19-25 (m/f), 26-59 (m/f), ≥60 (m/f)	≥60	P, L, PA: 3 levels (ages 19-59 years)
Romania	1990	[18]	All ages	0-12	1-3, 4-6, 7-9, 10-12, 13-15 (m/f)	16-19 (m/f), 20-45 (m/f), 46-62 (m), 46-60 (f), ≥63 (m), ≥61 (f)	≥63 (m), ≥61 (f)	PA: 3 levels (ages 20-60 years)
Russian Federation ^j	1991	[29]	All ages	0-3, 4-6, 7-12	1-3, 4-6, 7-10, 11-13 (m/f), 14-17 (m/f)	18-29 (m/f), 30-39 (m/f), 40-59 (m/f), 60-74 (m/f), ≥75 (m/f)	≥75	P, L: age <7 m, ≥7 m, PA: 5 levels (m), 4 levels (f)
Serbia ^k	1994	[41]	1-14 years	not set	1, 2, 3-4, 5-6, 7-9, 10-11 (m/f), 12-14 (m/f)	not set	12-14	daily needs group, pre-school-and-school institution group

Table 4 Continued*

Source	Age				Other characteristics			
	Year	Ref no.	Age span	Age groups 0–12 months	Age groups 1–18 years	Age groups adults (years)	Upper age group (years)	
Slovakia	1997	[19]	All ages	0–6, 7–12	1–3, 4–6, 7–10, 11–14 (m/f), 15–18 (m/f)	19–34 (m/f), 35–59 (m), 60–74 (m), 35–54 (f), 55–74 (f), ≥75 (m/f)	≥75	P, L, PA: 4 levels (ages 19–59 years (m) and 19–54 years (f)), 2 levels (ages 15–18 years) P: second half, L
Spain ¹	2007	[30]	All ages	0–5, 6–12	1–3, 4–5, 6–9, 10–12 (m/f), 13–15 (m/f)	16–19 (m/f), 20–39 (m/f), 40–49 (m/f), 50–59 (m/f), ≥60 (m/f)	≥60	
The former YR Macedonia	2001	[28]	All ages	0–3, 4–6, 7–9, 10–12	1–3, 4–6, 7–10, 11–14 (m/f), 15–18 (m/f)	19–24 (m/f), 25–50 (m/f), 51–64 (m/f), ≥65 (m/f)	≥65	P, L, preschool-in-kindergarten and school institution group P, L: >4 months, <4 months P, L
United Kingdom ^m	1991	[36]	All ages	0–3, 4–6, 7–9, 10–12	1–3, 4–6, 7–10, 11–14 (m/f), 15–18 (m/f)	19–50 (m/f), ≥51 (m/f)	≥51	
EC ⁿ	1993	[6]	≥6 months	6–12	1–3, 4–6, 7–10, 11–14 (m/f), 15–17 (m/f)	≥18 (m/f)	≥18	
WHO/FAO ^o	2004	[50]	All ages	0–6, 7–12	1–3, 4–6, 7–9, 10–18 (m/f)	19–50 (m/f), 51–65 (m/f), ≥66	≥66	P, L

*Based on recommendation report. Croatia, Federation of Bosnia and Herzegovina and Republika of Srpska (entities of Bosnia and Herzegovina) and Montenegro are excluded from the table because no recommendation report was available for the author and information could not be extracted from the questionnaire. The Czech Republic was excluded due to lack of published source.

Nordic countries = Denmark, Finland, Iceland, Norway, Sweden; The former YR Macedonia = The former Yugoslav Republic of Macedonia; EC = European Commission; WHO/FAO World Health Organization/ Food and Agricultural Organization

^m male, ^f female,

^{m/f} Recommendations defined for males and for females separately; these recommendations do not have to differ between males and females,

^P pregnancy,

^L lactation,

^{PA} physical activity,

^o based on questionnaire only

^aVit D, E, B12, folate, sodium, potassium, calcium, magnesium, iron, copper, phosphorus, selenium, iodine: no separate recommendation for male and female. Vit C: separate recommendations for male and female for all age groups. Vit D, E, B6, B12, folate, riboflavin, thiamin, niacin, iron (P), sodium, potassium, selenium, copper, iodine: no separate age groups for P and L. Magnesium: ≤18, 19–30 age, ≥31 years for P and L. Vit D: 19–50, ≥71 years. Vit B6, B12, calcium: 19–50, ≥51 years (vit B6 (19–50 years), vit B12, calcium: no separate recommendations for male and female). Sodium: 19–50, 51–70, ≥71 years and no separate recommendations for male and female. Magnesium: 19–30, ≥31 years and for 14–18 years no separate recommendations for male and female

^bMinerals: 0–5, 6–11 months. Trace elements: 0–3, 4–5, 6–11 months. Iron (11–14, 15–18 and 19–59 years): separate recommendation for menstruating/non-menstruating women. Sodium (0–5, 6–11 months): based on weight

^cVit C: separate recommendation for smokers. Footnotes in local language were not taken into account

^dVit D, C, B12, folic acid, phosphorus, copper, selenium and Vit B6 (10–12, 13–14 years): no separate recommendation for male/female. Vit E, Iodine (1–3, 4–6, 7–9 years): separate recommendation for male/female. Iron: separate recommendation for menstruating/non-menstruating women. Vit C: separate recommendation for non-smokers/smokers. Calcium, phosphorus, magnesium: separate recommendation for P and L for <19 and ≥19 years

^eMinerals: 1–3, 4–6, 7–9, 10–12, 13–19 (m/f), 20–65 (m/f), 66–74 (m), 56–74 (f), ≥75 years. Vit C: separate recommendation for smokers above ten cigarettes/day and for pregnant women in the third trimester
^fIron: separate recommendation for menstruating/non-menstruating women. Calcium (≥50 years): separate recommendation for post-menopausal women with/without oestrogen therapy

^gMinerals (≥19 years): separate recommendation for males and females
^hCalcium, vit D, thiamin, riboflavin, niacin: 4–8, 9–13, 14–18, 19–50, 51–70, >70 years. Vit B6: 4–8, 9–13, 14–18, 19–50, ≥51 years. Vit B12, folate: age groups: 4–8, 9–13, 14–18, ≥19 years. Iron, zinc: for pregnancy separate recommendation for first/second/third trimester. Copper: pregnancy third trimester. Riboflavin, thiamin: separate recommendation for male and female. Calcium, phosphorus, zinc, Vit B6 (0–5 months): separate recommendation for breast-feeding/bottle feeding. Vit D: separate recommendation for no exposure to sunlight/light coloured skin/remain outdoor for at least 15 min a day with at least hands and face uncovered. Vit D: separate recommendation for 51–60 and 61–70 years. Vit A: recommendation per gram PUFA. Zinc (>3 months): separate recommendation

^hVit D: separate recommendation for infants >4 weeks and elderly people with little or no sun exposure. Folate (31–60 years): separate recommendation for women in reproductive age/not in reproductive age. Iron: recommendation according to meal composition, and separate recommendation for post-menopausal women. Zinc: separate recommendation for vegetarians. Calcium, phosphorus (18–20 years): separate recommendation

ⁱCopper: 0–5 months, 7–10, 11–17, ≥18 years

^kMinerals: no separate recommendation for male and female

^lFolic acid: recommendation for first and second half of pregnancy

^mVit D (≥51 years): separate recommendation for ≤65/>65 years. Thiamin: recommendations for last trimester of pregnancy only

ⁿThiamin, niacin, vit B6: recommendation according to body weight, energy or protein intake. Thiamin: recommendation for >10 weeks of pregnancy. Iron (≥18 years): separate recommendations to cover of 96 and 90% of the population and postmenopausal women

^oMinerals: recommendation for first, second, third trimester of pregnancy, and 0–3, 3–6, 7–12 months of lactation. Iodine: <5, 6–12, 13–18 years (m/f). Zinc: separate recommendation for three levels of bioavailability. Zinc (0–12 months): separate recommendation for breast feeding/bottle feeding. Iron: separate recommendation for four levels of bioavailability. Iron: separate recommendation for pre-menarche/post menarche. Calcium: separate recommendation for breast feeding/cow milk-feeding. Magnesium: separate recommendation for breastfeeding/formula feeding. Vit B6 (51–65 years, m): separate recommendation for 19–50/>50 years. Vit D (51–65 years, m): separate recommendation for 19–50/51–65 years

for one population group, the mean of all given values was used. In case of a range, the mid value was used. In cases where recommendations were not given in the most common unit, values were converted into that unit. Standardized recommendations for vitamin A and vitamin D were compared per sex at the ages 3, 9 months and 5, 10, 15, 25, 50 and 70 years. These ages were selected because they indicate points of time in the different population groups as defined by countries. More population groups were defined for children and adolescents and therefore more ages between 0 and 18 years were selected. Also comparisons of recommendations for pregnant and lactating females were made. To depict the diversity between recommendations for vitamin A and vitamin D, boxplots were constructed in SPSS version 12.0.

In exploring commonalities and differences between micronutrient recommendations, background information extracted from the questionnaires and recommendation reports was compared focusing on the following items that could help to explain the commonalities and differences found:

1. The concept of recommendation (RDA, AI),
2. The year of publication of the recommendations (proxy for available evidence),
3. Population groups for which recommendations were defined,
4. Other methodological issues from the paradigm used to establish recommendations as selected criteria of adequacy or health endpoints (e.g. preventing deficiencies, plasma concentration), the type of evidence used (e.g. review of randomized controlled trials (RCT), experts' opinion), and assumptions made (e.g. physical activity, weight, sunlight).

Information on the first three items was extracted from the recommendation reports and information on the last item came mainly from the questionnaires.

Results

■ Data collation

Of the total 35 questionnaires sent out, 32 have been completed. No reaction after follow up was received from Montenegro and the Russian Federation. No reaction from Iceland was received due to a delay in sending the questionnaire.

From 31 European countries, WHO/FAO, and the EC the latest versions of reports on nutrient recommendations were collected, including varying amounts of background documentation. At the time of publication of this paper, reports from Republika Srpska (entity of Bosnia and Herzegovina) and Croatia had just become available and could therefore

Table 5 Overview of micronutrient recommendations on vitamin A (μg) for selected population groups in Europe*: males

Source			Population group							
Ref no.	Year	Country	3 months	9 months	5 years	10 years	15 years	25 years	50 years	70 years
[4]	2005	Albania	400	500	400	600	900	900	900	900
[16]	2006	Belgium	350	350	400	500	700	700	700	700
[27]	2005	Bulgaria	375	400	450	600	800	800	800	800
[13]	2004	DACH countries	500	600	700	900	1,100	1,000	1,000	1,000
[45]	2006	Estonia		300	350	600	900	900	900	900
[25]	2001	France	350	350	450	550	700	800	800	800
[1]	2005	Hungary	420	400	500	700	1,000	1,000	1,000	1,000
[12]	1999	Ireland	350	350	400	500	700	700	700	700
[42]	1996	Italy		350	400	500	700	700	700	700
[22]	2001	Latvia	375	375	500	700	1,000	1,000	1,000	1,000
[24]	1999	Lithuania	420	400	500	700	1000	800	800	800
[11]	1992	Netherlands	450	400	500	1,000	1,000	1,000	1,000	1,000
[34]	2004	Nordic countries		300	350	600	900	900	900	900
[53]	1996	Poland	450	450	500	600	700	700	700	700
[18]	1990	Romania	450	450	600	900	1,050	1087.5	1087.5	1,050
[29]	1991	Russian Federation	400	400	500	700	1,000	1,000	1,000	1,000
[41]	1994	Serbia			500	1000				
[19]	1997	Slovakia	400	400	500	700	1,000	950	950	850
[30]	2007	Spain	450	450	300	1,000	1,000	1,000	1,000	1,000
[28]	2001	The former YR Macedonia	375	375	400	700	1,000	1,000	1,000	1,000
[36]	1991	United Kingdom	350	350	400	500	700	700	700	700
[6]	1993	EC		350	400	500	700	700	700	700
[50]	2004	WHO/FAO	375	400	450	600	600	600	600	600

*DACH countries = Austria, Germany, Switzerland; Nordic countries = Denmark, Finland, Iceland, Norway, Sweden; The former YR Macedonia = The former Yugoslav Republic of Macedonia

EC European Commission, WHO/FAO World Health Organization/Food and Agricultural Organization

Croatia, Federation of Bosnia and Herzegovina and Republika of Srpska (entities of Bosnia and Herzegovina) and Montenegro are excluded from the table because no recommendation report was available for the author. The Czech Republic was excluded due to lack of published source

not be included in this paper. Reports from Federation of Bosnia and Herzegovina (entity of Bosnia and Herzegovina) and Montenegro were not received after follow up. No national report on nutrient recommendations has been published for the Czech Republic, but among others they use the EC recommendations (J. Ruprich, Personal communication, January 2008).

■ Available nutrient recommendations in Europe

Current publications on nutrient recommendations in Europe are listed in Table 2. Most of the reports (22 out of 33) were published from the year 2000. The oldest report dates from 1990 (Romania) and the most recent one is published in 2007 (Spain).

Table 2 also shows that 22 countries and WHO/FAO and the EC have their own reports on nutrient recommendations (own, own + adopted and own + shared). Thirteen countries based their recommendations on those from other countries or organisations (own + adopted). Five countries (France, Latvia, Lithuania, the Netherlands and the United Kingdom), WHO/FAO and the EC defined their own recom-

mendations (own). The DACH-countries as well as the Nordic countries cooperated in setting recommendations, indicated by 'shared' in Table 2. Greece and Portugal use the EC and the WHO/FAO recommendations respectively and Slovenia adopted the recommendations of the DACH-countries. The publication from which Albania and Federation of Bosnia and Herzegovina adopted their recommendations was not clear. The origin of recommendations was unknown for 2 countries (Romania and the Russian Federation).

■ Concepts and definitions used to define micronutrient recommendations

Different terms have been used for the total set of nutrient recommendations (DRIs, DRVs RDAs etc.). Within these sets, different terms have been used to express the levels of requirement and the certainty with which they have been set. Though terminology differed substantially between countries (e.g. recommended nutrient intake, recommended daily amount of absorption, recommended intake, population ref-

Table 6 Overview of micronutrient recommendations on vitamin A (μg) for selected population groups in Europe*: females

Source			Population group									
Ref no.	Year	Country	3 months	9 months	5 years	10 years	15 years	25 years	50 years	70 years	Pregnancy	Lactation
[4]	2005	Albania	400	500	400	600	700	700	700	700	760	1250
[16]	2006	Belgium	350	350	400	500	800	600	600	600	700	950
[27]	2005	Bulgaria	375	400	450	600	700	700	700	700	775	1150
[13]	2004	DACH countries	500	600	700	900	900	800	800	800	1,100	1500
[45]	2006	Estonia		300	350	600	700	700	700	700	800	1,100
[25]	2001	France	350	350	450	550	600	600	600	600	700	950
[1]	2005	Hungary	420	400	500	700	800	800	800	800	1,000	1,200
[12]	1999	Ireland	350	350	400	500	600	600	600	600	700	950
[42]	1996	Italy		350	400	500	600	600	600	600	700	950
[22]	2001	Latvia	375	375	500	700	1,000	1,000	1,000	1,000	1,100	1,300
[24]	1999	Lithuania	420	400	500	700	800	800	800	800	1,000	1,200
[11]	1992	Netherlands	450	400	500	800	800	800	800	800	1,000	1,250
[34]	2004	Nordic countries		300	350	600	700	700	700	700	800	1,100
[53]	1996	Poland	450	450	500	600	600	600	600	600	950	950
[18]	1990	Romania	450	450	600	900	1,050	950	950	900	900	900
[29]	1991	Russian Federation	400	400	500	700	800	900	900	800	1,100	1,300
[41]	1994	Serbia			500	800						
[19]	1997	Slovakia	400	400	500	700	900	850	850	800	1,100	1,200
[30]	2007	Spain	450	450	300	800	800	800	800	800	800	1,300
[28]	2001	The former YR Macedonia	375	375	400	700	800	800	800	800	1,000	1,200
[36]	1991	United Kingdom	350	350	400	500	600	600	600	600	700	950
[6]	1993	EC		350	400	500	600	600	600	600	700	950
[50]	2004	WHO/FAO	375	400	450	600	600	500	500	600	800	850

*DACH countries = Austria, Germany, Switzerland; Nordic countries = Denmark, Finland, Iceland, Norway, Sweden; The former YR Macedonia = The former Yugoslav Republic of Macedonia;

EC European Commission, WHO/FAO World Health Organization/Food and Agricultural Organization

Croatia, Federation of Bosnia and Herzegovina and Republika of Srpska (entities of Bosnia and Herzegovina) and Montenegro are excluded from the table because no recommendation report was available for the author. The Czech Republic was excluded due to lack of published source

erence intake, acceptable range, recommended daily allowance, acceptable intake range, recommended average daily intake, safe intake level, minimal intake, recommended safe level), all these concepts could be considered as equivalent to three basic concepts: RDA, AI (as defined by IOM [35]) and the acceptable range which is defined as a range of intakes high enough to avoid deficiency and low enough to avoid undesirable toxic effects [6]. Only the Hungarian publication included a deviating term, safe intake, which is defined as the recommended level of intake that is sufficient for 100% of the healthy population (Table 3). For Albania, Estonia, Latvia, Romania, Slovakia, Spain, and The former Yugoslav Republic of Macedonia, the concept of the recommendation (RDA or AI) was not clear from the reports and questionnaires. For most nutrients an RDA was defined, but for sodium, potassium, selenium, copper, vitamin D, vitamin E, and magnesium, an AI was often given instead. Besides a term considered equivalent to the RDA, the Polish recommendations also included the term recommended intake, representing the intake that meets the nutritional needs of 100% individuals in a healthy population.

■ Population groups

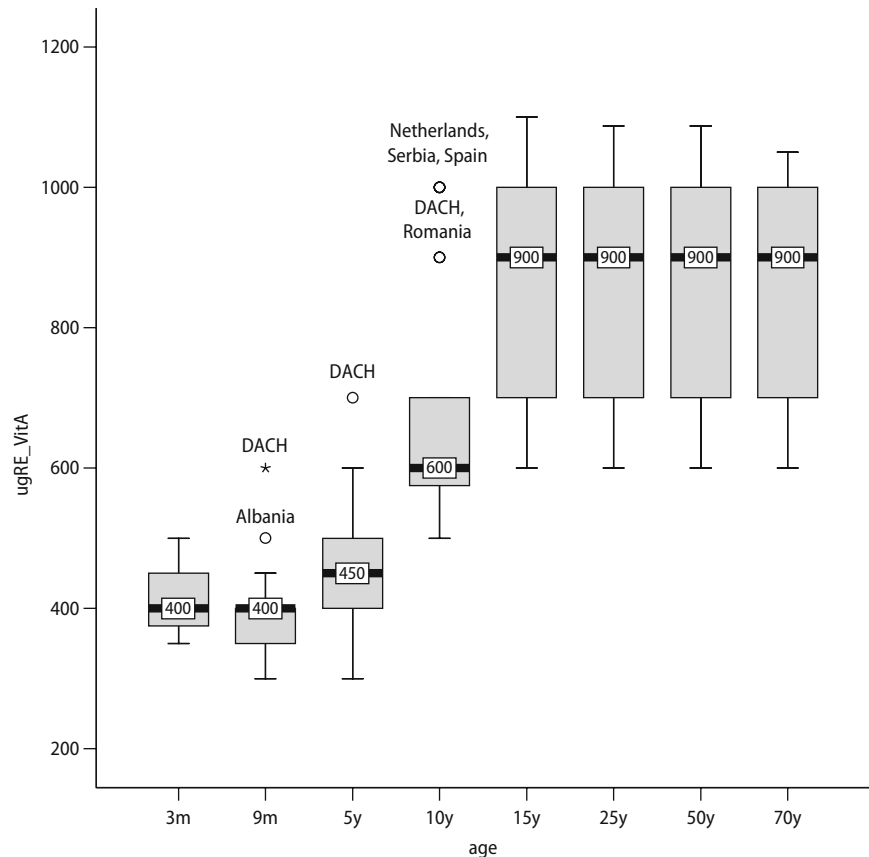
Age span

Table 4 lists the population groups encountered in the collated reports on nutrient recommendations. Deviations from generally defined population groups per country are given in foot notes. Table 4 shows that except for a few countries, most recommendations cover all ages. Exceptions include Estonia, Italy, and the EC, which do not give recommendations for infants under 6 months, and Serbia provides values only for children ages 1–14 years. Lithuania covers people up to the age of 65 years.

Children and adolescents

The first year of life is split up in two to four age categories. For the age span of 1–18 years, the grouping of ages differs substantially: the number of age categories varies between four and six and different age cut-off points are used. All publications, except for the Netherlands, start to separate recommendations for males and females between the age of

Fig. 1 Diversity of vitamin A recommendations for males in Europe expressed in μg retinol equivalents (RE) for selected ages. *x*-axis age = 3, 9 months and 5, 10, 15, 25, 50 and 70 years. *y*-axis μg RE vitamin A. *DACH = Austria, Germany and Switzerland. The boxes indicate the interquartile range (IQR = $x_{75}-x_{25}$) in which the median (x_{50}) of all vitamin A recommendations is indicated by a horizontal line. Vertical lines connected to the upper and lower side of the box indicate values less than 1.5 IQR below the first quartile or above the third quartile. Values not included in this range are considered as an outlier and are indicated by open dots (more than three times IQR above x_{75} or below x_{25}) and stars (more than 1.5 times the IQR above x_{75} or below x_{25})



10–15 years. The report from the Netherlands provides gender-specific separate recommendations from the age of 1 year, although the actual recommendations for men and females do not differ for all age groups and nutrients.

Adults

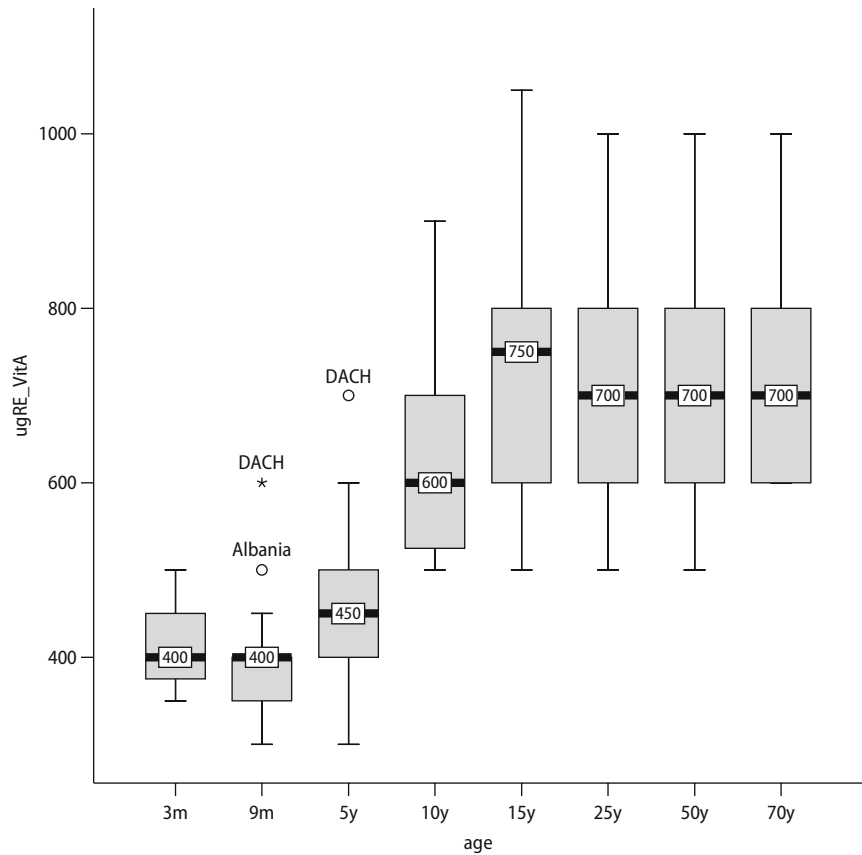
The number of age categories defined for adults varies from one to five but most reports include recommendations for four age categories. Discrepancies also emerge for the higher age levels. Most often the highest age group is ≥ 60 , ≥ 65 , or ≥ 75 years of age. The United Kingdom recommendations, however, have ≥ 51 years as an upper age group, the Italian recommendations defined ≥ 51 years for females and ≥ 60 years for males, both the Albanian and the Latvian recommendations defined the upper age group as ≥ 19 years and the European recommendations as ≥ 18 years. All countries, except Latvia, give recommendations separately for males and females, although Latvia does separate recommendations on minerals for the two sexes.

Other criteria considered in setting micronutrient recommendations

All countries except Romania provide separate micronutrient recommendations for pregnant and lactating females. The Albanian and the Bulgarian recommendations for both pregnant and lactating females are further split up in ≤ 18 years and ≥ 19 years. The United Kingdom and the Russian Federation split up the group of lactating females according to the period of lactation (≤ 4 months and >4 months for the United Kingdom and <7 months ≥ 7 months for the Russian Federation).

Some countries distinguish physical activity levels (PAL) per age group. Lithuania provides micronutrient recommendations for four PAL and two different body weights per age category and sex. The Russian Federation splits up the recommendations for adults in five PAL for males (1.4, 1.6, 1.9, 2.2, and 2.5), and four levels for females (1.4, 1.6, 1.9, and 2.2). Poland, Romania and Slovakia distinguish three PAL: low, moderate and high. In addition Slovakia also gives recommendations for students with and without physical workload. For specific nutrients other sub-

Fig. 2 Diversity of vitamin A recommendations for females in Europe expressed in μg retinol equivalents (RE) for selected ages. *x*-axis: age = 3, 9 months and 5, 10, 15, 25, 50 and 70 years. *y*-axis: μg RE vitamin A



groups are sometimes distinguished, for example for vitamin C, Bulgaria and the DACH-countries provide a separate recommendation for smokers. Other characteristics influencing requirements that are mentioned in recommendations for specific nutrients are: sunlight exposure, skin colour, menstrual blood loss, energy intake (especially for thiamin, riboflavin, niacin), protein intake (vitamin B6) or fat intake (vitamin E) and bioavailability for the nutrients iron and zinc.

■ Diversity in recommendations on vitamin A and vitamin D

Vitamin A

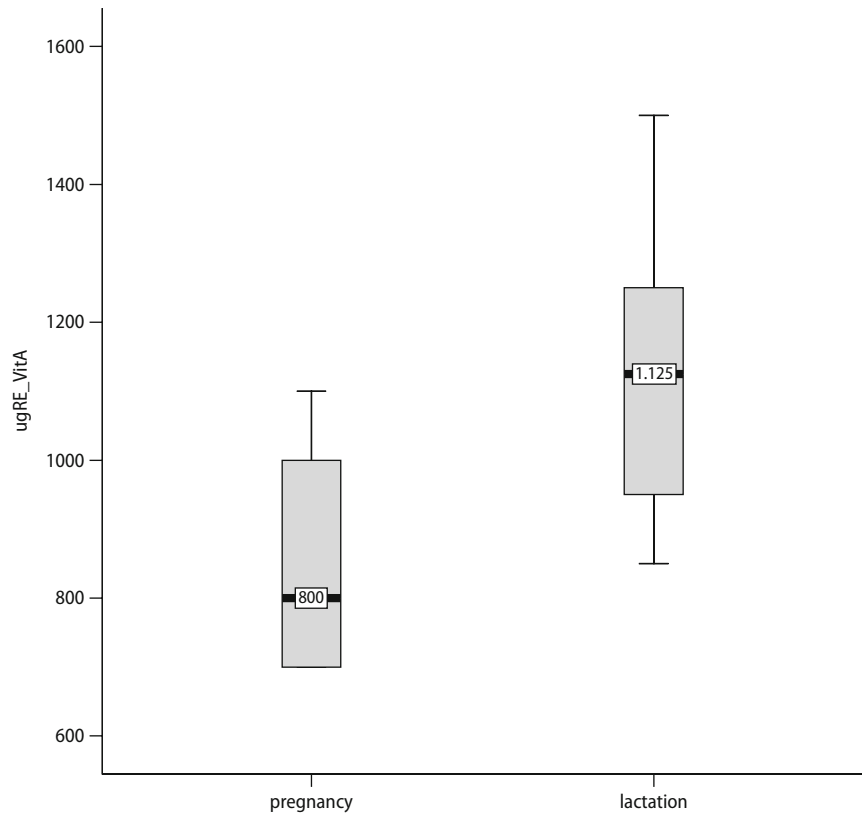
Tables 5 and 6 present the current available standardized recommendations for vitamin A (retinol equivalents, RE) by country and sex. Figures 1, 2 and 3 show the variability in these recommendations in box plots.

The median recommended intake of vitamin A for males is 400 μg for ages 3 and 9 months, 450 μg for age 5, 600 μg for age 10, and 900 for age 15, 25, 50 and 70 years.

For females median recommendations are the same to those for males of 3 and 9 months, and of 5 and 10 years old. For the other ages the median recommendation for females is 750 μg (15 years) and 700 μg (>15 years), which is lower than for males, i.e. 900 μg for ages ≥ 15 years. Vitamin A recommendations from the EC, Ireland, Italy, and the United Kingdom are lower than the median for all ages for both males and females and recommendations from Belgium only for males. Recommendations higher than the median for all ages are found in the DACH-countries, and Romania for both males and females.

For males the largest absolute difference in vitamin A recommendations between countries amounts to 500 μg RE/day (range at 10 years: 500–1,000 μg ; range at 15 years: 600–1,100 μg). The smallest range is observed at age 3 months, i.e. 150 μg (range: 350–500 μg). For females, the largest variation is found at the ages 25 and 50 years, with a range of 500–1,000 μg RE/day. The smallest difference is similar to that found for males. For pregnant females the median for vitamin A recommendations is 800 μg and for lactating females 1,125 μg . The individual European recommendations range from 700 to 1,100 μg and from 850 to 1,500 μg for pregnant and lactating females, respectively.

Fig. 3 Diversity of vitamin A recommendations for pregnant and lactating females in Europe expressed in μg retinol equivalents (RE) for pregnant and lactating women. *x*-axis; pregnancy, lactation. *y*-axis; μg RE vitamin A



When comparing methodological approaches for European vitamin A recommendations, all publications provide an RDA, except the Netherlands recommendations, which provide an AI (Table 2). The defined population groups in the different recommendations vary largely (Table 4). However, in each publication vitamin A recommendations are mostly the same from the age of 15 up to 70 years. Comparing publication dates, Spain and the DACH-countries that were published more recently provided high values, although the relatively high Netherlands recommendations were published in 1992 and the low WHO/FAO recommendations in 2004.

The criteria for adequacy or the health endpoints used for defining vitamin A recommendations, were not always reported in the questionnaire responses or background documents (data not shown). 'General health' and 'preventing deficiencies' were most frequently mentioned. In the Netherlands (high values) Belgium (values just below the median) and the DACH-countries (high values) 'an adequate reserve in the liver' was the main functional criteria of nutritional adequacy. Most vitamin A recommendations are based on data from observational cohort studies, or expert committees. Information on the type of evidence on which recommendations were based was, however, not always clear from the questionnaire re-

sponses and the type of evidence was unknown for some countries (Lithuania, Serbia, The former Yugoslav Republic of Macedonia) (data not shown). If, and what, assumptions were made when defining vitamin A recommendations was not clear from the information provided in the questionnaires response or from the reports.

Vitamin D

Table 7 and 8 and Figures 4, 5 and 6 present an overview of the available standardized recommendations on vitamin D. The median of recommended intake for males is 10 μg for age 3 and 9 months, 6.25 μg for age 5 years, 5 μg for age 10, 25 and 50 years and 7.5 μg for age 15 and 70 years. For females the medians of vitamin D recommendations are the same as for men, except for the median at age 70 years which is 10 μg for females and 7.5 μg for males.

No publication includes values that are below the median for all ages. In the Netherlands (except for men at age 70 years), the Russian Federation (>1 year) and the United Kingdom (≤ 64 years) vitamin D recommendations are below the median. The differences between countries are largest for infants in the age of 3 and 9 months, with values ranging from

Table 7 Overview of micronutrient recommendations on vitamin D (μg) for selected population groups in Europe*: males

Source			Population groups							
Ref no.	Year	Country	3 months	9 months	5 years	10 years	15 years	25 years	50 years	70 years
[4]	2005	Albania	5	5	5	5	5	10	10	
[16]	2006	Belgium	12.5	12.5	7.5	6.3	6.3	6.3	6.3	10
[27]	2005	Bulgaria	5	5	5	5	5	5	5	10
[13]	2004	DACH countries	10	10	5	5	5	5	5	5
[45]	2006	Estonia		10	7.5	7.5	7.5	7.5	7.5	10
[25]	2001	France	22.5	22.5	5	5	5	5	5	5
[1]	2005	Hungary	10	10	10	10	10	5	5	5
[43]	2006	Iceland		10	10	10	10	10	10	15
[12]	1999	Ireland	8.5	7	5	5	7.5	5	5	10
[18]	1996	Italy		17.5	5	5	7.5	5	5	10
[19]	2001	Latvia	10	10	10	10	10	5	5	5
[20]	1999	Lithuania	10	10	5	5	5	5	5	5
[22]	2000	Netherlands	5	5	2.5	2.5	2.5	2.5	2.5	7.5
[10]	2004	Nordic countries		10	7.5	7.5	7.5	7.5	7.5	10
[25]	1996	Poland	10	10	10	10	10			5
[27]	1990	Romania	10	10	10	10	7.5	5	5	5
[29]	1991	Russian Federation	10	10	2.5	2.5	2.5	2.5	2.5	2.5
[41]	1994	Serbia			10	10				
[19]	1997	Slovakia	7.5	10	7.5	7.5	10	7.5	5.8	5
[30]	2007	Spain	10	10	10	5	5	5	10	15
[28]	2001	The former YR Macedonia	7.5	10	10	10	10	5	5	5
[36]	1991	United Kingdom	8.5	7	0	0	0	0	0	10
[6]	1993	EC		17.5	5	5	7.5	5	5	10
[50]	2004	WHO/FAO	5	5	5	5	5	5	5	15

*DACH countries = Austria, Germany, Switzerland; Nordic countries = Denmark, Finland, Norway, Sweden; The former YR Macedonia = The former Yugoslav Republic of Macedonia;

EC European Commission, WHO/FAO World Health Organization/Food and Agricultural Organization

Croatia, Federation of Bosnia and Herzegovina and Republika of Srpska (entities of Bosnia and Herzegovina) and Montenegro are excluded from the table because no recommendation report was available for the author. The Czech Republic was excluded due to lack of published source

5 μg (Albania, Bulgaria, Netherlands and WHO/FAO) to 22.5 μg (France) and smallest for the ages of 5, 10, 15, 25 and 50 years with values ranging from 2.5 μg (the Russian Federation, the Netherlands) to 10 μg a day.

Similar recommendations for vitamin D are given for pregnant and lactating females, varying from 5 to 11.3 μg , with a median of 10 μg . The former Yugoslav Republic of Macedonia gives the highest recommendation and Albania, Bulgaria, the DACH countries, Romania, and the WHO/FAO (5 μg) the lowest.

Most countries provide an RDA for vitamin D, except for Belgium (acceptable range and AI), the EC (acceptable range), France (AI), and the Netherlands (AI). These AIs and acceptable ranges are not higher over all ages than the other recommendations. The lowest recommendations were published by the Russian Federation and the United Kingdom in 1991 but also by the Netherlands in 2000.

In general, criteria for adequacy on which recommendations are based are 'health' and 'prevention of deficiency as measured by the serum level of 25-hydroxy vitamin D3'. 'Appropriate bone formation' is

mentioned as a criterion for adequacy in the questionnaire from Belgium, Italy, and the Netherlands (data not shown). Vitamin D recommendations appear to be based most often on expert's opinion or on values that are borrowed from another country. Several countries reported that some assumptions were made when setting up vitamin D recommendations: the Italian recommendations are based on the assumption that in the Italian environment sun exposure guarantees adequate physiological vitamin D production. They provide a range starting from 0 μg for people with an adequate sun exposure. The upper level of the range applies to people without sunlight exposure (10 or 25 μg depending on the age). Also the United Kingdom recommendations for adults are 0 μg a day, based on the assumption that sun exposure will provide the amount sufficient for an adequate vitamin D status during summer and allow for stores to be laid down to support vitamin D status in winter. The Netherlands recommendations define normal exposure to sunlight as daily 15 min with at least hands and face uncovered, whereas the Nordic countries assume that exposure of the face, arms,

Table 8 Overview of micronutrient recommendations on vitamin D (μg) for selected population groups in Europe: females

Source			Populations groups									
Ref no.	Year	Country	3 months	9 months	5 years	10 years	15 years	25 years	50 years	70 years	Pregnancy	Lactation
[4]	2005	Albania	5	5	5	5	5	10	10		5	5
[16]	2006	Belgium	12.5	12.5	7.5	6.3	6.3	6.3	6.3	10	10	10
[27]	2005	Bulgaria	5	5	5	5	5	5	5	10	5	5
[13]	2004	DACH countries	10	10	5	5	5	5	5	10	5	5
[45]	2006	Estonia		10	7.5	7	7.5	7.5	7.5	10	10	10
[25]	2001	France	22.5	22.5	5	5	5	5	5	5	10	10
[1]	2005	Hungary	10	10	10	10	10	5	6	6	10	10
[43]	2006	Iceland	10	10	10	10	10	10	10	15	10	10
[12]	1999	Ireland	8.5	7	5	5	7.5	5	5	10	10	10
[42]	1996	Italy		17.5	5	5	7.5	5	10	10	10	10
[22]	2001	Latvia	10	10	10	10	10	5	5	5	10	10
[24]	1999	Lithuania	10	10	5	5	5	5	5	5	10	10
[14]	2000	Netherlands	5	5	2.5	2.5	2.5	2.5	2.5	7.5	7.5	7.5
[34]	2004	Nordic countries		10	7.5	7.5	7.5	7.5	7.5	10	10	10
[53]	1996	Poland	10	10	10	10	10			5		
[18]	1990	Romania	10	10	10	10	7.5	5	5	5	5	5
[29]	1991	Russian Federation	10	10	2.5	2.5	2.5	2.5	2.5	2.5	10	10
[41]	1994	Serbia			10	10						
[19]	1997	Slovakia	7.5	10	7.5	7.5	10	7.5	5.8	5	10	10
[30]	2007	Spain	10	10	10	5	5	5	10	15	10	10
[28]	2001	The former YR Macedonia	7.5	10	10	10	10	5	5	5	11.3	11.3
[36]	1991	United Kingdom	8.5	7	0	0	0	0	0	0	10	10
[6]	1993	EC		17.5	5	5	7.5	5	5	10	10	10
[50]	2004	WHO/FAO	5	5	5	5	5	5	5	15	5	5

DACH countries = Austria, Germany, Switzerland; Nordic countries = Denmark, Finland, Norway, Sweden; The former YR Macedonia = The former Yugoslav Republic of Macedonia;

EC European Commission, WHO/FAO World Health Organization/Food and Agricultural Organization

Croatia, Federation of Bosnia and Herzegovina and Republika of Srpska (entities of Bosnia and Herzegovina) and Montenegro are excluded from the table because no recommendation report was available for the author. The Czech Republic was excluded due to lack of published source

hands, and legs to sunshine for 6–8 min, 2 to 3 times a week is more than adequate to satisfy the vitamin D requirements. However, they indicate that dietary vitamin D is essential to ensure satisfactory vitamin D at northern latitudes. In setting vitamin D recommendations for the Polish population sunlight exposure was considered to be too diverse between adults and therefore no recommendation for adults was set (data not shown).

Discussion

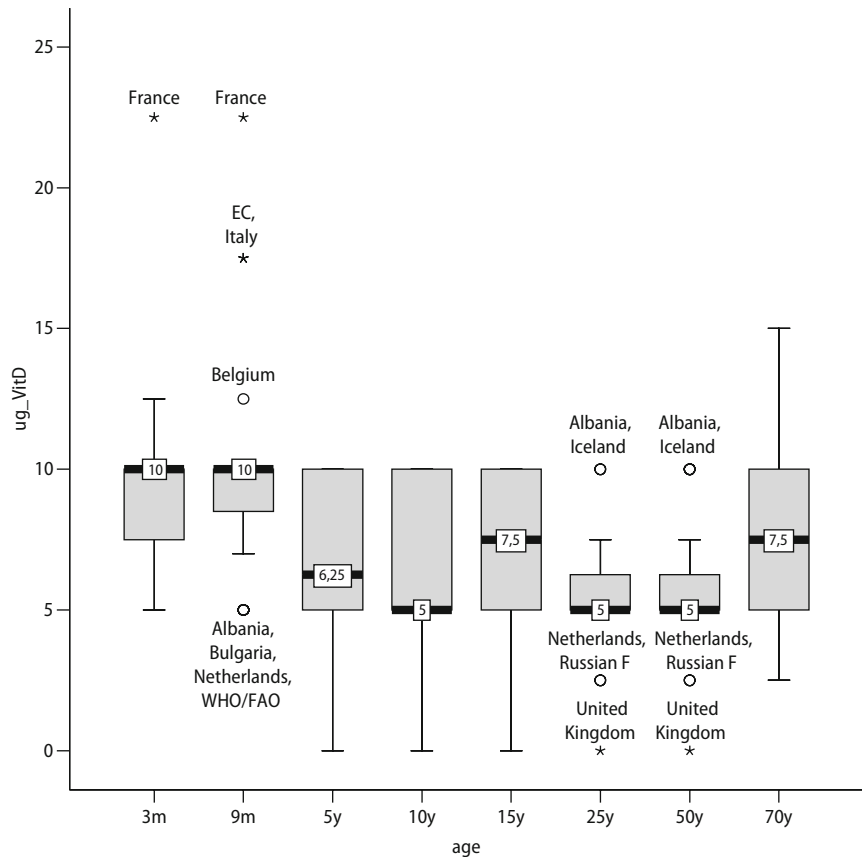
The results from this comparison of micronutrient recommendations show similarity in concepts and definitions used to establish recommendations on micronutrient intake in European countries, but also considerable diversity in defined population groups and levels of current recommendations was observed as illustrated by two vitamins. In exploring elements of the paradigm, differences between publications in criteria of adequacy, type of evidence used, and assumptions made, were recognized that could explain disparities in recommendations between countries.

■ Availability of current micronutrient recommendations

Many countries (13 out of 33) adopted recommendations from other publications, most frequently from the EC, WHO/FAO and IOM [6, 10, 50]. The EC report [6] was meant to provide practical advice and recommendations for a number of purposes including nutrition labelling and Community programmes on research and nutrition. The Scientific Committee for Food of the EC tried to harmonize existing national reports and also to include the most recent data. The WHO/FAO and the IOM publications both contain dietary reference values based on extensive scientific evidence evaluated by a large number of experts from all over the world or the United States/Canada respectively. They constituted an important source of information for all who work in the areas of nutrition, agriculture, food production and distribution, and health promotion [10, 50].

Due to the continuous changes in scientific knowledge, revisions of recommendations should be planned for every 5 to 10 years in order to keep them updated in the light of the most up-to-date scientific evidence [21, 52]. In view of this, the present overview

Fig. 4 Diversity in vitamin D recommendations for males in Europe expressed in μg for selected ages. x-axis age = 3, 9 months and 5, 10, 15, 25, 50 and 70 years. y-axis μg vitamin D. *The former YR Macedonia = The former Yugoslav Republic of Macedonia; DACH = Austria, Germany and Switzerland. The boxes indicate the interquartile range (IQR = $x_{75}-x_{25}$) in which the median (x_{50}) of all vitamin D recommendations is indicated by a horizontal line. Vertical lines connected to the upper and lower side of the box indicate values less than 1.5 IQR below the first quartile or above the third quartile. Values not included in this range are considered as an outlier and are indicated by open dots (more than three times IQR above x_{75} or below x_{25}) and stars (more than 1.5 times the IQR above x_{75} or below x_{25})



of recommendations is time bound, as some countries have already planned to revise their recommendations soon. Belgium, the Republika Srpska (entity in Bosnia and Herzegovina), the Czech Republic, Italy, Lithuania, Poland, Slovakia, the Netherlands and the United Kingdom will have some or all of their recommendations revised or set before 2010. The EC publication dates from 1993 and one of the tasks of the European Food Safety Authority (EFSA) is to update this advice from the Scientific Committee on Food on PRIs. The EFSA Panel on Dietetic Products, Nutrition and Allergies (NDA) intends to start revising the micronutrients PRIs in 2008. EURRECA on the other hand works towards a general framework including harmonized approaches, methods and key terms to be used for the development of micronutrient recommendations. Therefore EURRECA will work in close collaboration with EFSA, to improve the process and scientific basis on which micronutrient recommendations for European populations can be developed.

■ Concepts and definitions

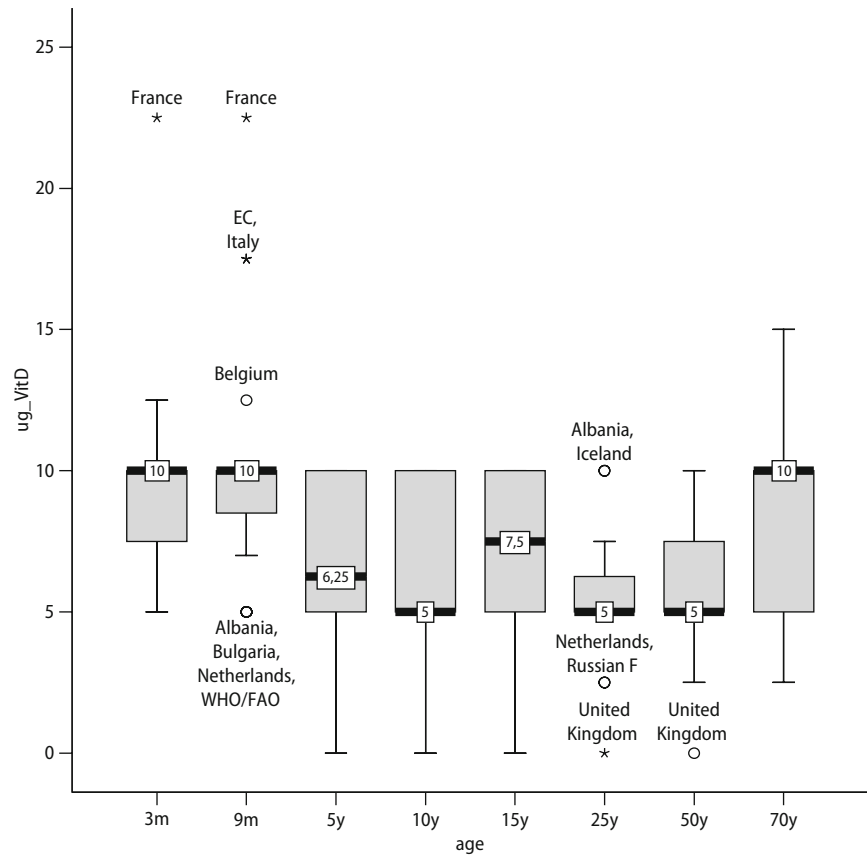
One of the factors that could explain differences between countries are the concepts and definitions which were used. However, all countries or regions

included in this paper used recommendations that were based on an EAR with the recommended value usually defined as 2 SD above the average. In the comparison of vitamin A recommendations it appears that all publications provide an RDA, except for the Netherlands recommendations that provide an AI (Table 2). By definition an AI is higher than the RDA and therefore could explain the relatively higher values of the Netherlands recommendations. Most countries provide an RDA for vitamin D, but the recommendations of countries that provide an AI or an acceptable range for vitamin D were not higher over all ages than the others.

■ Population groups in the current available micronutrient recommendations

To estimate the nutrient requirement of a specific population, first one needs data on requirements of a population with similar characteristics [21]. The definitions of age groups, each considered as relatively homogenous with regard to nutrient requirement, differ between countries, especially during childhood, puberty and at older age. This may be due to differences in reasoning in defining population groups; however in most publications these arguments are not

Fig. 5 Diversity in vitamin D recommendations for females in Europe expressed in μg for selected ages. x-axis age = 3, 9 months and 5, 10, 15, 25, 50 and 70 years. y-axis μg vitamin D

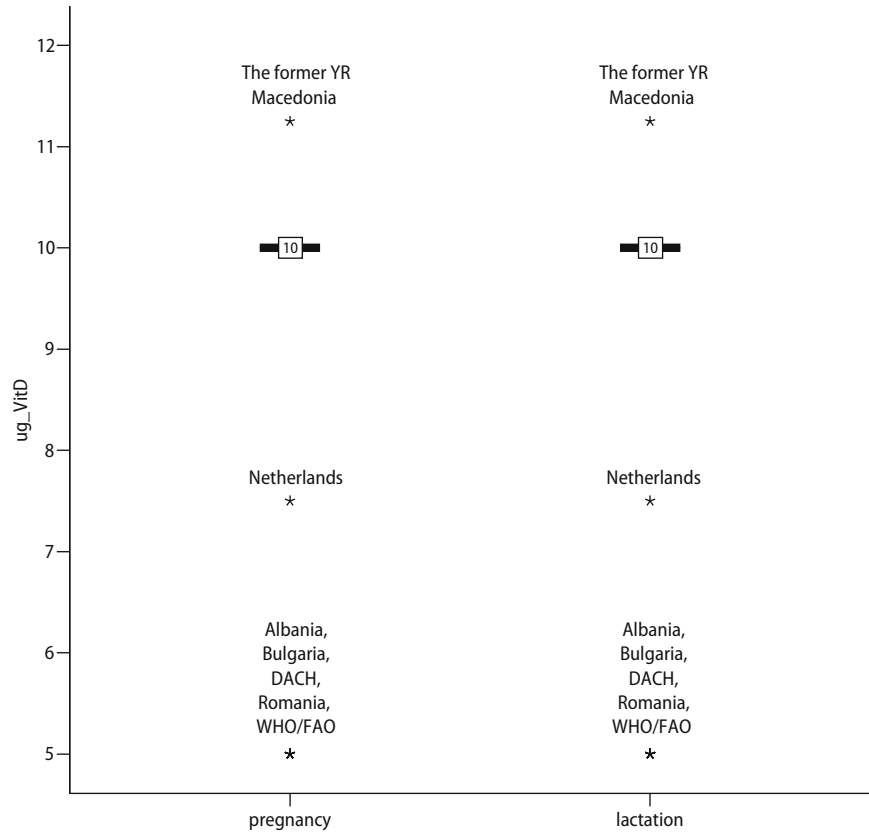


clearly described. An extreme example are the PRIs as published by the EC, that provide only one age group for adults (≥ 18 years) [6]. The report states that although elderly are prone to suffer from deficiencies due to a reduced food intake, inability to care for themselves or illness causing malnutrition, there is no evidence that micronutrient requirements of the elderly differ from those of middle-aged adults. Except for vitamin D the EC provide no different values for elderly. On the contrary, the Netherlands [14, 15], defined four age groups in adulthood, 19–21, 22–49, 50–64, and ≥ 65 years, using reference weights and heights from a representative sample of the population, and in doing so they follow the IOM [10]. These examples illustrate the differences in underpinning the definition of population groups.

In general, when data specific to physiological state are not available to estimate nutrient requirements, extrapolation from other growth states or a factorial approach, which estimates nutrient requirement based on the expected nutrient losses via e.g. urine, feces, and skin and accounting for differences in assumed bioavailability, are used instead [3, 52]. For some population groups, especially infants, children, adolescents, elderly, post-menopausal females, pregnant and lactating females, nutrient requirements are

often extrapolated from the adult RDA. For the recommendations included in this overview it is not clear whether values are originally based on average requirements of the population group, or if they are based on requirements estimated by the factorial approach or extrapolation. Only for infants (0 to 1 years) it is often indicated that nutrient values are extrapolated from the composition of breast milk. Prentice et al. [38] showed that the wide differences in perceived nutrient requirements between countries might be partly attributed to real physiological and environmental differences, but were mostly due to the differences in judgements about the best methodological approach to use and in the way theoretical approaches were applied. Unless sufficient data on nutrient requirements will be available for all life-stage groups some time, extrapolation from one group to another is necessary. The scientific basis for the method chosen should be completely transparent and thoroughly described for each nutrient and life stage group [3]. Atkinson and Koletzko [3] recommend that for the harmonization of dietary reference values, standardisation of age groups should be biologically based (growth and pubertal stages) with consideration of relevant developmental milestones throughout childhood. This requires agreement and

Fig. 6 Diversity in vitamin D recommendations for pregnant and lactating females in Europe expressed in μg for pregnant and lactating women. x-axis pregnancy, lactation. y-axis μg vitamin D



transparency on which data to use concerning growth standards, body sizes and composition, fetal and maternal accretion in pregnancy and milk composition, and on inclusion of appropriate adjustments (metabolic efficiency, weight change or physical activity).

In the comparison of vitamin A and vitamin D recommendations in this paper, values were mostly the same for the age of 15 up to 70 years within publications. Therefore it seems unlikely that differences in population groups are a key issue for disparities between publications. The definition of population groups might be an issue for other nutrients, but this needs to be studied further.

A few countries, Lithuania, Latvia, Poland, Romania and Slovakia, provide recommendations for different PAL. An explanation could be that these countries are all from eastern Europe where lifestyles might be less sedentary than in western Europe [47].

■ Criteria for adequacy, assumptions and type of evidence

As they may explain differences between recommendations, questions on the criteria/endpoint(s) used to determine adequate intake per nutrient were included

in the questionnaire. This information was, unfortunately, often not included in the received reports. However, the answers were often formulated in a very general manner, for example ‘health’ or ‘prevention of deficiencies’. This limited the comparison of criteria for adequacy. In all probability the question as included in the questionnaire was not clearly enough formulated, resulting in answers that were too less informative.

It is obvious that estimated requirements may vary with the endpoint or criteria for adequacy chosen. Nutrients have multiple sites of action in human metabolism and therefore it is possible to demonstrate abnormal function in one parameter measured or observed as a result of inadequate intake of a nutrient, while other parameters requiring the same nutrient intake appear adequate. For example a nutrient requirement based on the amount that prevents the clinical symptoms of a nutrient deficiency will be lower than one based on the amount that sustains nutrient stores or reserves [21]. Nutrient adequacy is a matter of definition, and may be a policy decision. Thus it is possible to have multiple requirements, each corresponding to a different indicator or criterion of adequacy. It is then up to nutrition and public health policy planners to determine which level of adequacy is desirable or

possibly attainable in the population group of interest [52].

Besides criteria for adequacy, the type of evidence used when establishing recommendations could explain differences between recommendations. In the questionnaire informants were asked to indicate the type of evidence that was used for each nutrient against a list with different possibilities (including RCT's, observational studies, mechanistic studies, experts' opinion, and borrowed from another country). Experts' opinion was the most frequently given answer, which unfortunately does not reveal on which types of evidence the experts have based their opinion, and how. Although some reports list all the experts that were included in the working groups, for the countries without clear background reports, this information was often missing.

The year of publication was used as a proxy for the age of the available scientific evidence. Even though publication years varied between 1990 and 2007, we cannot conclude that the year of publication was related to the level of the recommendation: For both vitamin A and vitamin D high intakes were recommended in both relatively old and recent publications, and the same was true for low values.

■ **Opportunities: what can EURRECA do with this information on the status quo?**

From the results of this comparison of micronutrient recommendations across Europe, it became clear that the concepts and definition used for setting them is quite similar throughout Europe. But even though many countries adopt and adapt recommendations from other publications, disparities remain. In our search for possible explanations for these disparities, we aimed at comparing different aspects of underlying approaches for setting up micronutrient values, but unfortunately there was a lack of transparency and completeness of the available information. An important opportunity for EURRECA is to develop tools to show how micronutrient recommendations can be devised for different population groups in a transparent manner. These tools should provide guidance on how to interpret data, how to take into account different criteria for adequacy and how to weigh different types of evidence in defining requirements. Expert committees throughout Europe can then use these tools to make decisions in a harmonized way and provide transparently based micronutrient recommendations.

In the EC call which led to the commissioning of EURRECA, vulnerable groups were identified as population groups that are prone to extremes of intake and those identified were: infants, children, adolescents, adults, pregnant and lactating females, post-meno-

pausal females, elderly, immigrants and low income groups. Our overview shows that immigrants, low-income, post-menopausal females were never a specified target groups in any recommendation report. The only exception is iron recommendations for post menopausal females. Within EURRECA variation in micronutrient needs based on micronutrient status, functional status and especially health and physiological status will be identified and parameters (biomarkers) for vulnerability will be explored. Based on this information population groups to be considered vulnerable will be identified. Guidance can then be given on whether and in what way micronutrient recommendations should be extended to these groups.

Conclusion

This paper provides an overview of the availability of micronutrient recommendations in Europe and provides information on the origin, concepts and definitions used, and population groups defined used for the setting of current available micronutrient recommendations in Europe. A comparison of vitamin A and vitamin D values is included in order to explore possible explanations for disparities between publications. The large variation in current recommendations for population groups as illustrated for vitamin A and vitamin D strengthens the need for guidance on setting evidence based, up-to-date European recommendations. Differences in criteria for adequacy or health endpoints, studies used to set recommendations, experts' opinions and assumptions are all likely to contribute to the identified variation, but the background information we collated does not allow us to disentangle the relative contribution of these different aspects due to lack of transparency. EURRECA has an excellent opportunity to develop tools to improve transparency on the approaches used, including the selection of criteria for adequacy. Weighing of evidence, and interpretation of data to support those who develop quality assured, evidence-based harmonized micronutrient recommendations across Europe and elsewhere.

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■ **Conflict of Interest** none.

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