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Review

Micronutrient supplement recommendations in pregnancy vary across a geographically diverse range of countries: a narrative review

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ABSTRACT

Specific food supplements are essential during preconception and pregnancy to ensure adequate intake of vitamins and minerals to support fetal growth and development and metabolic changes in the maternal body. Our objective was to identify food supplement recommendations, particularly those of folic acid, iron, Vitamin D, and iodine, during preconception and/or pregnancy across a geographically diverse range of countries. Further, we investigated whether country location and income-level related to the recommendations. We performed an electronic search and identified country-specific preconception and pregnancy food supplement recommendations, policy documents, and official guidelines of national organizations informing recommendations. To ensure the data were as accurate as possible, country-specific experts were contacted. Data were collected in 2017 and reevaluated in 2022. Country income level was determined by the World Bank classification. Each inspected country ($n = 43$) recommended folic acid supplementation, typically 400 µg/day, before and during pregnancy. About half of the countries recommended an iron supplement (dose range, 16–195 mg/day) and one quarter Vitamin D (typically 10 µg/d in higher latitudes) and iodine (150–200 µg/day). Country location and income level had some influence on the recommendations. Vitamin D was more often recommended in higher latitude, high-income countries. Almost all upper-middle and lower-middle income countries recommended iron supplementation, whereas less than one third of high-income countries had a corresponding recommendation. Findings suggest that food supplement recommen-

Abbreviations: NTD, neural tube defect; OECD, Organisation for Economic Co-operation and Development.

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dations for pregnant women vary across countries, likely influenced by geographic location as well as income level. These data may be used in the harmonization of food supplement recommendations.

1. Introduction

Maternal diet is the primary source of nutrients for the fetus during pregnancy [1]. Thus, a sufficient intake of various nutrients including vitamins and minerals during pregnancy and preconception is important to ensure proper growth and development of the fetus, but also to support the changes occurring in the maternal metabolism [2]. Metabolic demand of these nutrients may not be achieved by dietary intake alone [3], necessitating food supplements. This is of particular importance in groups of pregnant women who are at an increased risk of nutrient deficiency because of a restricted diet, including vegan diets, or a disease.

Several nutrients are known to have an important role during preconception or pregnancy. Folic acid has well-known beneficial effects, mainly in decreasing the risk for neural tube defects (NTDs) of the fetus [4]. In addition, Vitamin D and iodine are needed to support the brain development and skeletal growth of the fetus [5,6], whereas the need for iron increases because of increased blood volume to ensure the supply of essential hormones and nutrients to the fetus [7]. It should be noted, however, that an excess intake of vitamins or minerals may also be harmful, such as Vitamin A, which at high doses has teratogenic effects.

Despite the acknowledged role for vitamins and minerals during preconception and the periconception period, there remains a lack of consensus globally as to the specific requirements and the means by which these should be achieved by women wishing to conceive or who are already pregnant. Thus far, there are no comprehensive examinations or comparisons available for food supplement recommendations during pregnancy or preconception across the world. It is plausible that there may be differences among these recommendations resulting from geographic location, income level, as well as cultural reasons. The differences in food supplement recommendations may lead to consumer confusion and even lower consumption of the supplements. Here, we aimed to investigate (1) which nutrients (and at what doses) are recommended as food supplements during preconception or pregnancy and (2) whether the food supplement recommendations, specifically folic acid, iron, Vitamin D, and iodine, for pregnant women differ across a geographically diverse range of countries.

2. Methods

2.1. *Identification and selection of recommendations*

An investigation into national recommendations for use of food supplements (herbal and protein recommendations were excluded) during pregnancy was conducted between June and August 2017; any potential changes in the recommendations were reevaluated in August 2022. Food supplements are defined by the European Union's food legislation [8] as food products that differ from normal foods by either their appearance or the way in which they are used (tablet, capsule, or liquid form in measured doses) and do not provide significant amounts of energy. Countries from 6 continents (Asia, Africa, North America, South America, Europe, and Australia/Oceania) were included in the analyses for geographical and cultural diversity. For each continent, countries were selected to represent a range of economies (lower-middle, upper-middle, and high income) as classified by the World Bank (2022) [9]. All countries for which the health care system was previously determined according to the Rothgang-Wendt typology by Böhm and coworkers were included in this review [10,11].

We performed an electronic internet search using keywords related to pregnancy (pregnancy, preconception, antenatal, prenatal, gestational, maternal), supplement (supplement, nutrition, diet), and recommendation (recommendations, policy, guidelines). The purpose was to identify country-specific preconception and pregnancy food supplement recommendations and the policy documents and official guidelines of national organizations that informed these recommendations. National organizations included governments and their agencies and professional bodies and associations. For countries where English is not an official language, search terms were translated from English into the official language. No language restrictions were imposed, and documents were translated into English where necessary. In addition to the electronic search, to ensure the data were as accurate and up-to-date as possible, clinicians and researchers with country-specific expertise were contacted and asked to identify the national preconception and pregnancy supplementation recommendations in their country. The information provided by experts was used to validate the findings of the electronic searches. In addition, an electronic search was performed (PubMed, Web of Science) to identify published studies, and the available literature systematically reviewed. Country experts confirmed data for 5 countries (Brazil, China, Denmark, Finland, and New Zealand). For Canada, Spain, Australia, and India, the contacted experts were not in a position to validate the findings, but instead identified the documents in which the recommendations could be found. Forty-three countries were included in the final analysis. Because the recommendations were given by different authorities or societies and they are not uniformly referenced in the databases, we could only partly follow the PRISMA guidelines (i.e., not the whole process regarding methods and results sections).

2.2. Data extraction and analysis

Of the 43 included countries, 21 were from Europe, 4 from North America, 3 from South America, 3 from Australia/Oceania, 3 from Africa, and 9 from Asia. European countries were divided in to Western, Southern, Central/Eastern, and Nordic countries and Asian countries into Eastern, Southern, South-Eastern, and Middle East countries.

The following data were extracted from the documents for each nutrient: (1) the recommended supplementation dose; (2) the recommended duration of supplementation use; (3) the target group (i.e., pregnant women or all women of childbearing age) for supplementation; and (4) recommendations for high-risk subgroups. The data were tabulated according to countries' geographic region, income level, and health care system type. Recommendations were grouped into general or high-risk subgroup recommendations. We included 14 food supplements in the final analysis, with each investigated country having at least 1 recommendation.

3. Results

3.1. Official national organizations and health care systems providing recommendations for food supplement use during preconception and pregnancy

Official national organizations that informed preconception and pregnancy supplementation recommendations within the 43 investigated countries are presented in Supplemental Table S1. Ministries of health and societies for gynecology and obstetrics were the most common agencies that informed recommendations for pregnancy supplementation. The Nordic Council of Ministers was a common source of supplementation recommendations in all Nordic countries.

Of the 43 investigated countries, health care system types determined included [10,11]: National Health Service, national health insurance, social-based mixed-type, social health insurance, private health system, and Etatist Social Health Insurance (Supplemental Table S1). The health care system could not be identified for 17 countries. Two of these (Mexico and Turkey) belonged to the Organisation for Economic Co-operation and Development (OECD) but were not classified because of insufficient data [11]. The remaining countries ($n = 15$) were not members of OECD; thus, their health care system was not determined.

Etatist Social Health Insurance system, the most common system in OECD countries, is found in Asian countries (South Korea, Japan, Israel) and in some European countries (France, Netherlands, Poland, and Hungary). The National Health Service system, the second most common type, is predominant in European countries (Denmark, Finland, Iceland, Norway, Sweden, Portugal, Spain, and United Kingdom). National health insurance is common in Australia, New Zealand, Canada, Italy, and Ireland, whereas a social health insurance system is common in Western European countries (Switzerland, Luxembourg, Netherlands, and Austria). Slovenia was the only country belonging to a social-based mixed-type system and the United States was the only country with a private health system (Supplemental Table S1).

3.2. Nutrients recommended for us as food supplements during pregnancy and preconception

Folic acid, iron, Vitamin D, and iodine were the most frequently recommended nutrients and therefore are discussed in more depth (Table 1). In many countries, recommendations regarding Vitamin A supplementation existed; thus, it will also be discussed. The nutrients that were less frequently recommended during preconception or pregnancy were calcium, Vitamin B_{12}, Vitamin C, selenium, Vitamin B_6, Vitamin K, omega-3 fatty acids, magnesium, and multivitamins.

3.3. Folic acid

Folic acid supplementation during preconception or pregnancy was recommended by all the investigated countries (Table 1). In most countries, the recommended dose was 400 µg/day, but 3 countries recommended 5 mg/day for pregnant women (Table 2). Indonesia was the only country in which dosage was not specified. Canada recommended that folic acid should be taken as part of a multivitamin, whereas Ireland recommended the opposite (Table 2). High-risk subgroup recommendations were found in 36/43 countries. Risk factors were, for example, a previous pregnancy affected by NTD, a partner having a previous child with NTD, maternal diabetes or body mass index >30 kg/m^2. The most common recommended dose of folic acid for high-risk women was 4 to 5 mg/day (Supplemental Table S2). The countries that did not have high-risk subgroup recommendations were located in Africa, Central and Eastern Europe, and South and South-East Asia (Table 1).

3.4. Iron

Iron supplementation during (low-risk) pregnancy was recommended by 20 countries (Table 1). All investigated North and South American and African countries recommended iron supplementation for women with low-risk pregnancy. In addition, most Asian countries, but only a few countries located in Europe and Australia/Oceania, recommended iron supplementation (Table 1). Recommended dose ranged from 16 to 20 mg/day in Canada to 130 to 195 mg/day in Tanzania. Mexico was the only country to recommend iron supplementation during the preconception period and during pregnancy (Table 2). High-risk subgroup recommendations for women at risk of iron deficiency were found in 29 countries across all continents (Table 1). Recommended doses ranged from 30 mg/day (Norway and France) to 200 mg/day (India) (Supplemental Table S2).

3.5. Vitamin D

Vitamin D supplementation was recommended by 12 countries during low-risk pregnancy (Table 1). All Nordic countries recommended (low-risk) Vitamin D supplementation, except for Sweden, which had only a high-risk subgroup recommendation. In addition, Vitamin D recommendations existed in some Western and Central/Eastern European and Asian countries (Table 1). The recommended doses ranged from 5 µg/day

Table 1 – The number of countries with general or high-risk subgroup recommendations or both recommendations for using folic acid, iron, Vitamin D, iodine, and Vitamin A as supplements during preconception period or during pregnancy in the inspected countries by their geographic region.

Geographical region	Number of countries	Folic acid			Iron			Vitamin D			Iodine			Vitamin A		
		A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Europe	21	2	-	19	1	15	2	8	5	2	5	6	-	12	-	-
Western	8	-	-	8	-	8	-	4	1	1	1	3	-	4	-	-
Southern	3	-	-	3	1	1	1	-	2	-	2	-	-	2	-	-
Central and Eastern	5	2	-	3	-	2	-	1	2	-	2	1	-	1	-	-
Nordic	5	-	-	5	-	4	1	3	1	1	-	2	-	5	-	-
North America[1]	4	-	-	4	2	-	2	-	1	-	2	-	1	1	-	-
South America	3	-	-	3	1	-	2	-	1	-	-	-	-	1	-	-
Australia and Oceania	3	-	-	3	-	2	1	-	2	-	2	-	-	2	-	-
Africa	3	3	-	-	1	-	2	-	-	-	-	-	-	2	-	-
Asia	9	2	-	7	3	-	3	2	1	-	1	-	-	6	-	1
East	3	-	-	3	-	-	1	-	-	-	-	-	-	1	-	-
South	2	1	-	1	1	-	1	1	-	-	-	-	-	1	-	1
South East	2	1	-	1	1	-	-	-	-	-	-	-	-	2	-	-
Middle East	2	-	-	2	1	-	1	1	1	-	1	1	-	1	-	-

A, general recommendation for pregnant women or women preconception; B, recommendation for high-risk groups; C, general and high-risk subgroup recommendations.
[1] North America: Canada, El Salvador, Mexico, United States.

(Ireland) to 50 µg/day (Poland). In France, the recommendation was a single dose of 2500 µg. In 3 countries (Iceland, Norway, and United Kingdom), omega-3 and cod liver oil were reported to be acceptable alternatives for 10 µg of a Vitamin D supplement (Table 2). The countries that had a high-risk subgroup recommendation were located in all continents except for Africa, in which no Vitamin D recommendation existed at all (Table 1). For women at high risk, such as those with existing Vitamin D deficiency or poor sunlight exposure, the recommended dose ranged from 10 µg/day to 25 µg/day. Once again, in France, a single high-dose treatment (1 × 2500 µg) was recommended (Supplemental Table S2).

3.6. *Iodine*

Iodine supplementation was recommended by 11 countries during low-risk pregnancy (Table 1). These countries were in Europe, North America, Asia, and Australia/Oceania. The most common recommended dose was 150 to 200 µg/day but ranged between 100 and 150 µg/day (Germany) and 200 and 250 µg/day (Israel and Russia) (Table 2). High-risk subgroup recommendations for women with iodine deficiency resulting from, for example, a vegan diet, were found in 9 countries located in Europe, Asia, and North America (Table 1). The recommended doses ranged between a single 400-µg dose (El Salvador) and 100 to 150 µg/day (France and Finland) (Supplemental Table S2). There were no general or high-risk subgroup recommendations for iodine supplement use during pregnancy in African or South American countries (Table 1).

3.7. *Vitamin A*

Eighteen countries recommended that Vitamin A should not be used as a supplement during pregnancy because of its teratogenic effects (Table 1). However, a single 200,000-IU dose was recommended immediately after childbirth in 5 countries located in South America, Africa, and Asia (Table 2). High-risk subgroup recommendations for women with night blindness were found in 1 country (Nepal), where a 1-off dose of 25,000 IU was recommended (Supplemental Table S2).

3.8. *Other nutrients recommended during pregnancy or preconception*

Other recommended nutrients during low-risk pregnancies were calcium, Vitamin B_{12}, Vitamin C, and selenium (Supplemental Table S3). Four countries recommended calcium supplementation in the range of 600 mg/day (El Salvador) to 1 g/day (South-Africa and India) (Supplemental Table S4). Twelve countries recommended calcium supplementation for high-risk subgroups (i.e., women who consume little or no dairy products), in which case recommended doses ranged from 500 mg/day (Denmark, Finland, and Norway) to 1200 mg/day (El Salvador) (Supplemental Table S5). Vitamin B_{12} was recommended during low-risk pregnancies by only 2 countries (Supplemental Table S4), and a high-risk subgroup recommendation existed in 6 countries for women consuming a vegan diet (Supplemental Table S5). India was the only country recommending Vitamin C supplementation during pregnancy and New Zealand was the only country recommending that selenium supplements should not be used during pregnancy (Supplemental Table S4).

Vitamin B_6, Vitamin K, omega-3, magnesium, and multivitamin supplements were recommended only by a small number of countries and only for high-risk subgroups (Supplemental Table S3). Details are shown in Supplemental Table S6, but the recommendations were targeted for example at women using antiepileptic medication (Vitamin K), women with a low consumption of fish (omega-3), and women consuming a very limited diet (multivitamin).

Table 2 – General recommendations for using folic acid, Vitamin D, iron, iodine, and Vitamin A as supplements during preconception period or during pregnancy in the inspected countries by their geographic region.

Geographical region	Folic acid	Iron	Vitamin D	Iodine	Vitamin A
Europe					
Austria [a]	400 µg/day* Before conception until the 8th week of pregnancy/4 weeks before conception and throughout the first trimester [33,34]	-*	-	-	-
Bulgaria [b]	400 µg/day* At least 12 weeks before and 12 weeks after conception. Preferably continue supplementation throughout pregnancy [35]	-*	-*	-	Pregnant women should not take food supplements containing vitamin A, unless otherwise advised by a doctor
Denmark [a]	400 µg/day* From when the pregnancy is planned until the 12th week of pregnancy [32,36–40]	40–50 mg/day* From the 10th week of pregnancy onward [32,37,38,41]	10 µg/day* Throughout pregnancy [32,37,42]	-	Retinol supplements during pregnancy should be limited to no more than 3 mg/day unless other medical aspects argue for a higher intake. No harm of using beta-carotene supplements
Finland [a]	400 µg/day* 8 weeks before and 12 weeks after conception. [32,43]	-*	10 µg/day Throughout pregnancy [43]	-*	Retinol supplements during pregnancy should be limited to no more than 3 mg/day unless other medical aspects argue for a higher intake. No harm of using beta-carotene supplements[32,43]
France [a]	400 µg/day, 100–200 µg/day, and 400 µg/day* 4 weeks before, and 8 weeks after, conception/periconceptionally, 4 weeks before, and up to 12 weeks after conception [44–46]	-*	1 × 2500 µg dose (1-off dose)* At the beginning of the seventh month of pregnancy [47]	-*	Vitamin A (for a dose higher than the recommended intakes either 700 µg RE per day) may have teratogenic effects [46]
Germany [a]	400 µg/day* Four weeks before and 12 weeks after conception / Before conception until at least 12 weeks after conception[33,48,49]	-*	-*	100–150 µg throughout pregnancy. Kelp supplements are not recommended [49]	-
Hungary [a]	400 µg/day At least 4 weeks before and 12 weeks after conception [50]	-	-*	-*	-

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Table 2 (*continued*)

Geographical region	Folic acid	Iron	Vitamin D	Iodine	Vitamin A
Iceland [a]	400 µg/day* Four weeks before and 12 weeks after conception. [32,51,52]	-*	10 µg/day or cod liver oil/omega-3 preparations (5 mL/day) throughout pregnancy [32,51,52]	-	Retinol supplements during pregnancy should be limited to no more than 3 mg/day unless other medical aspects argue for a higher intake. No harm of using beta-carotene supplements. / Women who take fish liver oil need to remember to choose multivitamins that do not contain vitamin A [32,51]
Ireland [a]	400 µg/day* Should not be taken as part of a multivitamin. Throughout child-bearing years or at least 4 weeks before and 12 weeks after conception [53–58]	-*	5 µg/day throughout pregnancy [57,58]	-	Supplementation should be avoided and pregnant women should not consume supplements that may result in a daily intake of Vitamin A above the TUL (3 mg RAE/day). Women who are pregnant or who are actively planning a pregnancy should choose a vitamin and mineral preparation containing max 500 µg/day Vitamin A [54,57]
Italy [a]	400 µg/day* (may be part of a multivitamin if it does not contain Vitamin A, B-carotene is acceptable) Preconception and throughout the first 12 weeks of pregnancy / 4 weeks before conception and throughout the first trimester [59–62]	-*	-*	-	Supplementation with Vitamin A (intakes >700 µg/ day) should be avoided as potentially teratogenic [59,61]

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Table 2 (*continued*)

Geographical region	Folic acid	Iron	Vitamin D	Iodine	Vitamin A
Luxembourg [a]	400 µg/day* 4 weeks before and 12 weeks after conception [63]	-*	-	-	-
Netherlands [a]	400 µg/day / 400–500 µg/day * 4 weeks before and 8 weeks after conception/ 4 weeks before and 10 weeks after conception. [64,65]	-*	10 µg/day prior to pregnancy continuing throughout pregnancy	-	Supplementation is not recommended. Total intake should be <3 mg RAE/day
Norway [a]	400 µg/day* 4 weeks before and 8–12 weeks after conception [66–69]	-*	10 µg or cod liver oil/omega-3 preparations (5 mL/day) throughout pregnancy [68,69]	-*	Retinol supplements during pregnancy should be limited to maximum 3 mg/day unless other medical aspects argue for a higher intake. No harm of using beta-carotene supplements
Poland [a]	400 µg/day* Preconception [70]	-*	50 µg/day for women planning pregnancy	200 µg/day for women planning pregnancy and pregnant women	-
Portugal [a]	400 µg/day / no specified dose * Before stopping contraception, until the 12th week of pregnancy / at least 3 months before stopping contraception [71,72]	30–60 mg/day From weeks 14–16 onward [73]	-	150–200 µg/day Before stopping contraception and throughout pregnancy	-
Russia [b]	400 µg/day All first trimester [74]	-	-	200-250µg All pregnancy, the period of breast feeding	-
Slovenia [a]	400 µg* Before conception and throughout the first 12 weeks of pregnancy [75]	-	-	-	-
Spain [a]	400 µg/day* At least 4 weeks before conception until the end of the first trimester / 4-8 weeks before and 12 weeks after conception / 12 weeks before and 12 weeks after conception / 8–12 weeks before conception and throughout pregnancy [76–79]	30 mg/day* Second half of pregnancy [76,80]	-*	200 µg/day Preconception and throughout pregnancy [76,77,80]	Supplementation is not recommended [76,80]

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Table 2 (*continued*)

Geographical region	Folic acid	Iron	Vitamin D	Iodine	Vitamin A
Sweden [a]	400 µg/day* 4 weeks before conception and throughout the first trimester of pregnancy / Before conception or from when pregnancy is planned until the 12th week of pregnancy [32,81,82]	-*	-*	-	Retinol supplements during pregnancy should be limited to no more than 3 mg/day unless other medical aspects argue for a higher intake. No harm of using beta-carotene supplements
Switzerland [a]	400 µg/day* 4 weeks before and 12 weeks after conception [33,83–85]	-*	15 µg/day Throughout pregnancy [33,84,86]	-*	-
United Kingdom [a]	400 µg/day* Before conception until the 12th week of pregnancy [87–93]	-*	10 µg/day (as either vitamin D supplements or cod liver oil). Throughout pregnancy [89–96]	-	Pregnant women are advised not to take supplements containing vitamin A unless advised to by their doctor / Avoid any supplements that contain more than 700 µg of vitamin A [92,94]
North America					
Canada [a]	400 µg/day (as part of a multivitamin)* Ideally throughout child-bearing years; if not, then at least 8–12 weeks before conception, throughout the pregnancy [97–101]	16–20 mg/day (as part of a multivitamin). Throughout pregnancy [98,99,101]	-	150 µg/day Throughout pregnancy. [102]	Women should be cautioned not to take more than one daily dose of multivitamins. This will help women not exceed the TUL (3 mg RAE/day) [98]
El Salvador [c]	1 mg/day (alone) or 500 µg/day (combined with iron) or 800 µg every 2 days (combined with iron and Vitamin B_{12})* 12 weeks before conception Throughout pregnancy. [103–105]	60 mg/day combined *with folic acid or 30 mg every 2 days (combined with folic acid and Vitamin B_{12}) Throughout pregnancy [103–105]	-	200 mg/day* (Iodized oil capsule) Throughout pregnancy. [103]	-
Mexico [b]	400 µg/day* 12 weeks before and 12 weeks after conception / 12 weeks before conception and throughout pregnancy [106,107]	No dosage specified From the preconception period and throughout pregnancy [107]	-	-	-

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Table 2 (*continued*)

Geographical region	Folic acid	Iron	Vitamin D	Iodine	Vitamin A
United States [a]	400 µg/day / 400–800 µg / 600 µg * N/A: should be taken by all women capable of becoming pregnant. [97,108–110]	27 mg/day* Throughout pregnancy. [97,110]	-*	150 µg/day Throughout pregnancy. Avoid iodine or kelp supplements containing >500 µg/day [111]	-
South America					
Argentina [a]	400 µg/day* Before conception until the 12th week of pregnancy (NTD prevention) / Throughout the second and third trimesters (anemia prevention) [112–115]	60 mg/day* Throughout the second and third trimesters [112,113]	-*	-	-
Bolivia [c]	400 µg/day* At least 8 weeks before and 8 weeks after conception [116]	30 mg/day Throughout pregnancy [116]	-	-	-
Brazil [b]	400 µg/day / 5 mg/day* 30 days before and 12 weeks after conception / 30 days before conception and throughout pregnancy / 8–12 weeks before conception and throughout the first trimester [117–119]	40 mg/day* Throughout pregnancy until 12 weeks postpartum [117,119,120]	-	-	200,000 IU (1-off dose) Supplementation is not recommended for women living in states not covered by the supplementation program**. Immediately postpartum [119,120]
Australia and Oceania					
Australia [a]	400–500 µ/day* At least 4 weeks before and 12 weeks after conception / Before conception and during the first 12 weeks of pregnancy / From 12 weeks before and 12 weeks after conception. [121–124]	-*	-*	150 µg/day Kelp supplements are not recommended Before conception and throughout pregnancy [124,125]	Advise women that taking Vitamin A supplements is not of benefit in pregnancy and may cause harm [122]
New Zealand [a]	800 µg/day / 400 µg/day* At least 4 weeks before and 12 weeks after conception [126–128]	-*	-*	150 µg/day Before conception and throughout pregnancy [129]	Supplementation is not recommended, total intake from supplements, including fish oils, maximum 3 mg retinol/day

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Table 2 (*continued*)

Geographical region	Folic acid	Iron	Vitamin D	Iodine	Vitamin A
Papua New Guinea [c]	5 mg/week* Duration not specified [130]	65 mg/day (ferrous sulphate) / 87.4 mg/day (Fefol)* Duration not specified [130]	-	-	-
Africa					
Kenya [c]	400 µg/day From conception and throughout pregnancy / From first month of pregnancy or first contact [131,132]	60 mg/day* From conception and throughout pregnancy / From first month of pregnancy or first contact [131,132]	-	-	A 1-off 200,000 IU dose Immediately after delivery or within 8 weeks of delivery [133]
South Africa [b]	5 mg/day 12 weeks before conception and throughout pregnancy [134,135]	65 mg/day* Throughout pregnancy	-	-	-
Tanzania [c]	5 mg/day Throughout pregnancy. [136,137]	2-3 × 65 mg/day Throughout pregnancy [136,137]	-	-	200,000 IU (1-off dose) Immediately following childbirth, or as soon as possible up to 6 weeks postpartum [138]
Asia					
China [b]	400 µg/day* Whenever pregnancy is possible or at least 12 weeks before, and weeks after conception [139]	-	-	-	-
India [c]	500 µg combined with iron* For 100 days during pregnancy from 16th week onward [140,141]	100 mg/day* For 100 days during pregnancy from 16th week onward [140,141]	12.5 µg/day / 250 IU From 14 weeks of pregnancy up to 6 months postpartum [142]	-	-

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Table 2 (*continued*)

Geographical region	Folic acid	Iron	Vitamin D	Iodine	Vitamin A
Indonesia [c]	No dosage specified. No duration specified* [143,144]	No dosage specified. Throughout pregnancy and puerperium [143,144]	-	-	200,000 IU (1-off dose) Immediately postpartum [143]
Israel [a]	400 µg/day* At least 4 weeks before and 12 weeks after conception [145]	30 mg/day From the end of the third month of pregnancy until 6 weeks postpartum [145]	5-10 µg/day Throughout pregnancy [145]	150-250 µg/day At least 4 weeks before pregnancy and throughout pregnancy	-
Japan [a]	400 µg/day* Before conception. [146,147]	-	-	-	-
Nepal [c]	400 µg/day From the beginning of the second trimester in pregnancy until 45 days postpartum [148]	60 mg/day From the beginning of the second trimester until 45 days postpartum	-	-	200,000 IU (1-off dose)* Immediately following childbirth, or as soon as possible up to 6 weeks postpartum
Singapore [a]	At least 800 µg/day Before conception and throughout the first 12 weeks of pregnancy [149]	-	-	-	In the first trimester, pregnant women should obtain their Vitamin A from food rather than from supplements
South Korea [a]	400 µg/day* No duration specified [150,151]	30 mg/day* Throughout the second half of pregnancy	-	-	Supplementation is not recommended
Turkey [b]	400 µg/day* 4 weeks before and at least 12 weeks after conception [152]	16–60 mg/day* Throughout pregnancy [152]	-*	-	Intake of Vitamin A from vitamin-mineral and fish oil supplements should be controlled

Abbreviations: NTD, neural tube defect; RAE, retinol activity equivalents; TUL, tolerable upper intake limit.

[a] High-income level.

[b] Upper-middle-income level.

[c] Lower-middle-income level.

* See supporting information Table S2 for high-risk subgroup's recommendations.

** Women in the states of the Northeast Region and in the municipalities of the State of Minas Gerais (in the North of the State and in the Jequitinhonha of Mucuri) – regions where vitamin A deficiency is endemic

Table 3 – The number of general recommendations for folic acid, iron, Vitamin D, iodine, Vitamin A, calcium, Vitamin B_{12}, Vitamin C, and selenium supplementation during preconception period or during pregnancy in inspected countries by their income level (GNI per capita) classified by World Bank.

Supplement	High-income countries *n* (%) $n = 28$	Upper-middle-income countries *n* (%) $n = 7$	Lower-middle-income countries *n* (%) $n = 8$
Folic acid	28 (100)	7 (100)	8 (100)
Iron	8 (29)	4 (57)	8 (100)
Vitamin D	11 (39)	-	1 (13)
Iodine	9 (32)	1 (14)	1 (13)
Vitamin A	16 (57)	3 (43)	4 (50)
Calcium	-	1 (14)	3 (38)
Vitamin B_{12}	-	-	2 (25)
Vitamin C	-	-	1 (13)
Selenium	1 (3.6)	-	-

Country income groups as classified by the World Bank 2022 by gross national income (GNI) per capita: low income <$1085; lower-middle income $1086–4255; upper-middle income $4256–13,205; and high income >$13,205.

3.9. *Food supplement recommendations during pregnancy and preconception according to country health care system type*

The number of countries having general recommendations for investigated nutrients according to their health care system type are presented in Supplemental Table S7. In general, countries with National Health Service, national health insurance, and Etatist-Social Health Insurance systems had recommendations for more nutrients than countries belonging to other health care systems. Vitamin D was recommended in more than half of the countries belonging to National Health Service or Etatist Social Health Insurance systems, whereas only a few countries with other health care systems had corresponding recommendations. Iron was not generally recommended, with only a few countries belonging to National Health Service, national health insurance, and Etatist Social Health Insurance systems having recommendations. Iodine recommendations were found in each type of health care system except for social-based mixed-type.

3.10. *Food supplement recommendations during pregnancy and preconception according to country income level*

We evaluated country income level, defined by the World Bank, and its relation to the number of recommendations (Table 3). From the 43 investigated countries, 28 were high-income, 7 were upper-middle-income, and 8 were lower-middle-income countries (Supplemental Fig. S1). It was noted that country income level affected some, but not all recommendations. Folic acid supplementation was recommended by all countries. In contrast, iron supplementation was recommended by each lower-middle income country, and 4/7 upper-middle income countries, whereas only one third of high-income countries had a corresponding recommendation. Vitamin D and iodine recommendations were more common in high-income countries than upper- or lower-middle-income countries (Table 3).

3.11. *Vitamin D recommendations according to country location and income level*

The number of general Vitamin D recommendations was also investigated by country geographical region and income level (Table 4). Overall, high-income European countries recommended Vitamin D supplementation more often when compared with upper-middle- and lower-middle income level countries that were located in each continent. More specifically, supplementation was generally recommended in Northern European countries. In addition, one half of the Western European countries and 1 Central/Eastern European country had general recommendations, whereas no such recommendation was found in Southern European countries. Of the high-income countries that were not located in Europe, only 1 Middle-Eastern country (Israel) recommended Vitamin D supplementation during pregnancy. Upper-middle income countries did not recommend Vitamin D supplementation, whereas only 1 lower-middle income country (India) did.

4. Discussion

This study aimed to investigate which food supplements are recommended during preconception and pregnancy and whether there are differences in the recommendations, including by geographical location, health service system, or income. We found that the most commonly recommended supplements for pregnant women in this geographically and economically diverse sample were folic acid, iron, Vitamin D, and iodine. Folic acid recommendations were universal, whereas recommendations for supplemental intake of other nutrients varied between the countries, particularly for iron, Vitamin D, and iodine. Country income level and geographic location may to some extent explain the differences in recommendations set for pregnant women.

Recommendations to use folic acid as a supplement before and during pregnancy were made by each investigated country. The importance of folic acid supplementation in fetal development has been understood since 1992, when a random-

Table 4 – Inspected countries that have general recommendations for Vitamin D supplementation and number of recommendations by geographical region and country income level (GNI per capita) classified by World Bank.

Geographic region	High-income countries	Upper-middle-income countries	Lower-middle-income countries
	$n = 28$	$n = 7$	$n = 8$
Europe			
Western	5/10	-	-
Southern	0/3	-	-
Central and eastern	1/3	0/2	-
Nordic	4/5	-	-
Asia			
East	0/2	0/1	-
South	-	-	1/2
South East	0/1	-	0/1
Middle East	1/1	0/1	-
North America	0/2	0/1	0/1
South America	0/1	0/1	0/1
Australia and Oceania	0/2	-	0/1
Africa	-	0/1	0/2

Country income groups as classified by the World Bank 2022 by gross national income (GNI) per capita: low income <$1085; lower-middle income $1086–4255; upper-middle income $4256–13,205; and high income >$13,205.

ized controlled study found that multivitamin supplementation, including 800 µg of folic acid, decreased the risk of NTDs [12]. A subsequent study proved that an equivalent risk reduction could be achieved with lower doses of 400 µg/day [13]. In addition to decreasing the risk of NTDs, there is evidence that folic acid supplementation may decrease the risk of metabolic disturbances, such as insulin resistance [14] and even gestational diabetes mellitus [15]. Further, it may exert beneficial effects on the child's long-term neurodevelopment [16]. There seems to be a clear understanding of the importance of folic acid supplementation during pregnancy for fetal development, which likely explains the consistency of the supplement recommendations.

Altogether, just under one half of the investigated countries recommended iron supplementation during low-risk pregnancies. Maternal anemia, often caused by iron deficiency, is a common public health problem across the world, causing various adverse effects for a mother and a child, such as fatigue and fetal growth restriction [17]. It was recognized as a key area for action within the UN Sustainable Development Goals that set out to halve the prevalence of anemia in women of reproductive age by 2030 [18]. Previously, it has been reported that iron deficiency differs by geographical area, being more common in African and South-Asian countries and less common in high-income countries [17]. This is in line with our observation that iron supplementation was recommended more frequently in upper- and lower-middle income countries than in high-income countries. Thus, it is plausible that iron supplementation is recommended in countries in which deficiency is more common. Although iron deficiency is less common in high-income countries, a recent review reported that as many as 32% of the women of reproductive age in Europe had an iron deficiency, but only 5% had anemia [19]. This indicates that there may be a need to improve the iron status, perhaps via modifying the current national recommendations for iron supplement use in the high-income countries, where it is currently afforded lower priority.

Previously, it has been observed that Vitamin D deficiency is common in the adult population but also specifically in pregnant women in various countries [20]. Vitamin D deficiency may have numerous undesirable consequences; it has been linked with a lower birth weight, poorer growth and neurodevelopment of infants, and autoimmune diseases [21,22]. On the other hand, prior evidence indicates that Vitamin D supplementation during pregnancy may have various benefits, such as a lower risk of gestational diabetes mellitus [23] and preeclampsia [24]. Despite its benefits, Vitamin D supplementation did not appear to be generally recommended for pregnant women, with only 12/43 of the investigated countries recommending its supplementation during low-risk pregnancies. Vitamin D was most commonly recommended in Europe, particularly in Nordic countries in which sunlight exposure is limited. However, some Asian countries also recommended Vitamin D supplementation. Surprisingly, not all the countries situated at higher latitudes (i.e., Canada and Sweden), recommended Vitamin D, at least during low-risk pregnancies. Interestingly, in Canada, folic acid and iron are recommended to be taken as part of a multivitamin, which usually also contains Vitamin D.

Iodine is an essential nutrient for fetal neurodevelopment [25], as it is needed in thyroid hormone production, which increases during pregnancy. Iodine deficiency is one of the most common nutrient deficiencies in the world [26]; despite this, only one quarter of the countries recommended iodine supplementation during low-risk pregnancy. Globally, universal salt iodization (WHO and UNICEF, 1995), rather than supplements, is the primary strategy to decrease iodine deficiency. For example, in Finland, the endemic intake of iodine is low, but the use of iodine-enriched salt has remarkably decreased iodine deficiency [27], although pregnant women and their infants may still be iodine insufficient [28]. This raises a question whether the iodine supplement recommendations should be reevaluated for pregnant women because, thus far, there are no common recommendations for pregnant women. Recom-

mendations are mainly set for the women identified as at higher risk for deficiency, despite the evidence that (1) this may be a common issue across the pregnant population and (2) even mild to moderate deficiency may have detrimental consequences [29]. To solve this, more research is needed to evaluate the iodine status of pregnant women. It might be judicious to reconsider recommendations on iodine supplementation in a country-specific way (i.e., while considering implementation of salt iodization program and iodine status of the vulnerable groups).

The physiological adjustments, for example, in glucose metabolism, occurring during pregnancy are relatively similar in all pregnant women. Therefore, the reasons behind the diverse cross-country food supplement recommendations are likely from other factors. Geographic location of the country may influence the need for food supplements, as, for example, countries situated in a higher latitude have restricted sunlight exposure especially during the wintertime and therefore a greater requirement for dietary Vitamin D. In addition, sunlight exposure (and consequently Vitamin D synthesis) may be limited for cultural reasons (i.e., if the skin is covered with clothes or a veil). Geographic location may also affect the endemic intake of nutrients (e.g., Finland, where the level of iodine in soil is low), although actions have been undertaken to improve the iodine status through salt iodination. Differences in the predominant culture, religion, or dietary preferences between countries may also affect intakes of key nutrients and therefore requirements for additional supplementation. One example of this is Japan, where the absence of iodine supplementation recommendations likely reflects the assumed iodine sufficiency of the population although, despite this historical sufficiency, significant within-country differences and generational shifts in intakes over time are being reported [30]. In addition, the availability of food products, and type of products, such as Vitamin D–fortified dairy products affects intake and thus the need for food supplements. Indeed, large-scale food fortification programs have been shown to be a cost-effective approach to increasing micronutrient density of the diet, with success of particular relevance to pregnancy being the iodization of salt and the fortification of flour with folic acid, as recently reviewed [31].

Cooperating in recommendation setting would be one feasible way to increase cohesion in food supplement recommendation. For example, Nordic countries (Denmark, Finland, Iceland, Norway, and Sweden) have collaborated in the determination of dietary recommendations (Nordic Nutrition Recommendations, 2023) [32]. Despite this, the recommendations are still not the same; for example, unlike other Nordic countries, Sweden does not recommend Vitamin D supplementation for pregnant women. It is common that there is more than one organization producing recommendations within a country, which may cause confusion if the recommendations are not in line; for example, both France and the United States have multiple, overlapping recommendations for folic acid supplementation (Table 2). On the other hand, in some countries, no recommendations exist at all, or they do not reach the target population, necessitating further research. The data from this study could be used in the harmonization of food supplement recommendations to decrease conflicting information. However, if the recommendations are harmonized, various factors need to be considered, including the targeted population, geographic location of the country, and dietary habits and culture. Hence, it may be inappropriate to harmonize all the food supplement recommendations across countries.

A strength of our research is the number and diversity of countries examined. The countries were geographically and culturally diverse being located across all 6 continents. In addition, we sampled to ensure representation of all health care system types and a range of income levels. It was not possible, however, to include all countries, and the authors acknowledge that there are some omissions that warrant further research, specifically countries from Central or South America. One limitation of our study relates to language issues. Because most of the recommendations were not available in English, there might be inaccuracies in the translations. There was also a low response rate to the requests for expert validation of our findings that, combined with the reluctance of some experts to confirm the data identified, may suggest a lack of confidence in their own knowledge of the local recommendations and therefore a need for better communication and dissemination of the recommendations.

5. Conclusions

To conclude, folic acid supplementation was recommended by every country putatively because of its well-known benefits. There was more variation in the recommendations regarding iron, Vitamin D, and iodine supplementation, and it is likely that the country location as well as income level and health care system type affect these recommendations. The findings of this study may be used in the evaluation of the needs for harmonization of food supplement recommendations. However, the individual and population differences should be considered if the recommendations are harmonized.

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Supplementary materials

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