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# Micronutrient status of populations and preventive nutrition interventions in South East Asia

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## Abstract

*Objectives* Since the 1990s, programs for the control of micronutrient deficiencies became a public health priority for many governments, including the countries partnering the project "Sustainable Micronutrient Interventions to Control Deficiencies and Improve Nutritional Status and General Health in Asia" (SMILING): Cambodia, Indonesia, Laos-PDR, Thailand and Vietnam. The aim of this study was to map which micronutrient deficiencies have been addressed and which interventions were in place in the SMILING countries. *Methods* The mapping covered the period up to 2012. Updated information from relevant surveys after 2012 is included in this paper after the completion of the SMILING project. The mapping of micronutrient status was limited to either national or at least large-scale surveys. Information on nutrition interventions obtained through a systematic mapping of national programs combined with a snowball collection from various sources. *Results* Among the five SMILING countries, Thailand differed historically by an early implementation of a nationwide community-based nutrition program, contributing to reductions in undernutrition and micronutrient deficiencies. For Cambodia, Indonesia, Laos PDR, and Vietnam, some national programs addressing micronutrients have been implemented following adjusted international recommendations. National surveys on micronutrient status were scattered and inconsistent across the countries in design and frequency. *Conclusion for practice* In conclusion, some micronutrient deficiencies were addressed in national interventions but the evidence of effects was generally lacking because of limited nationally representative data collected. Improvement of intervention programs to efficiently reduce or eliminate micronutrient deficiencies requires more systematic monitoring and evaluation of effects of interventions in order to identify best practices.

**Keywords** Micronutrient · Deficiency · Southeast Asia · Vitamin · Mineral · Vitamin A · Iron · Zinc · Children · Women of reproductive age

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## Significance

Micronutrient deficiencies are thought to affect over 2 billion people worldwide, and many programs are in place to improve micronutrient status of vulnerable groups. However, it is often unclear why programs are focusing on a specific micronutrient deficiency. The present study aimed to map the prevalence of micronutrient deficiencies among young children and women of reproductive age in five South-East Asian countries, as well as provide an overview of programs in place to address micronutrient deficiencies. The study shows that there exists an huge gap in data on current micronutrient status. Most national representative studies on micronutrient status either use proxy-indicators for micronutrient status, such as anemia for iron status, or are over 20 years old. To be able to monitor the impact of programs or interventions to improve micronutrient status, more systematic surveys should be conducted on fixed intervals

## Introduction

The World Summit for Children in 1990 marked the beginning of a coordinated global commitment to major reductions in selected micronutrient deficiencies (vitamin A, iron and iodine) by the turn of the millennium. The implementation of large-scale programs for the control of micronutrient-deficiency control became a priority public health concern for many governments. By the turn of the millennium, majority of developing countries had national policies and programs to address deficiencies of the three key micronutrients; vitamin A, iodine and iron (Deitchler et al. 2004), including the countries partnering the "Sustainable Micronutrient Interventions to Control Deficiencies and Improve Nutritional Status and General Health in Asia" project (acronym: SMILING): Cambodia, Indonesia, Laos PDR, and Vietnam. In Thailand, progressed to be a middle-income country, the historical context differed by the early implementation of a nationwide community-based nutrition program during the 1980s to mid-1990s, contributing to marked reductions in undernutrition and micronutrient deficiencies (Winichagoon 2013). However, by the turn of the millennium, the targeted elimination of vitamin A and iodine deficiencies was far from being reached on a global scale, and the aimed reduction of iron deficiency was also unachieved. During the last decade, it became clear that certain interventions, such as the high-dose vitamin A supplement for women directly after delivery, were ineffective, and the World Health Organization has changed its recommendations accordingly. However, many governments in Southeast Asia have not updated their policies regarding improving micronutrient status of vulnerable groups.

This study reports the situation for micronutrient status and key nutrition interventions in Cambodia, Indonesia, Laos PDR, Thailand and Vietnam, the five countries partnering the SMILING project 2012–2014. The mapping of nutritional status and interventions covered the period up to 2012. Updated information from relevant surveys after 2012 is included in this paper after the completion of the main survey. Information on micronutrient status covered in the mapping was limited to either national or at least large-scale surveys. Information on relevant nutrition interventions was obtained from various national sources.

The aim of the study was to provide an overview for the governments and organization working on nutrition in the region on which micronutrient deficiencies have been addressed as a public health problem and which interventions have been in place. It is hypothesized that the parallel mapping of the current and past situation in countries with regional connection is valuable for enabling exchange of information within the region and strengthen the capacity for improvement of current policies to combat micronutrient deficiency in Southeast Asia.

## Background

### The SMILING Countries

The landscape of malnutrition in the five SMILING countries in Southeast Asia are historically impacted by political, economic, social and cultural conditions which have formed the policies and the implementation of programs addressing the micronutrient challenges in the region. Nutritional status, including micronutrient status, is influenced by the nutrient contributed by the daily diets along with nutrients supplemented through targeted nutrition programs, such as supplementation and food fortification. The SMILING countries have a similar food culture dominated by a rice based diet and with traditional preferences for aquatic food sources—fish, crustacean (scrimp, crawfish), mollusc (mussels, clams) and to some extend also amphibian (frogs, snakes) and insects (Burlingame et al. 2006). The food cultures also have in common that the dietary diversity is high with a traditional use of a various wild plants and animals. However, the access to this diversity of foods is restricted by poverty and impacts nutrition across the region (Dixon et al. 2007; Muslimatun and Wiradnyani 2016; McDonald et al. 2015).

Preventing micronutrient deficiencies in women of reproductive age, before and during pregnancy, and in infants and young children is essential not only for their immediate good, but also for the health benefits that last their entire lives and even for future generations (ref to paper3 in the supplement?). The SMILING countries represent a range of historically determined scenarios for economic and social development, under which the prevalence and severity of undernutrition (stunting, wasting, and micronutrient malnutrition) in children and women have been shaped.

The SMILING project overall aimed to investigate and give recommendations for the use of science-based evidence for effectively implementing nutrition actions. This requires an understanding of specific nutritional problems and their complex causes, and engagement of a broad range of stakeholders, especially policy makers that need to be informed how specific investment in nutrition is feasible for their country.

## Nutrition and Food Systems

In a global view, micronutrient deficiencies were the central focus for nutrition interventions over a period of two decades following the agenda set at the 1990 World summit for Children. More recently, actions supporting a better linkage between nutrition interventions and the development of the agriculture and food systems have received international attention to approach more sustainable and long-term solutions (Black et al. 2013). There is political recognition of the importance of multi-disciplinary and multi-stakeholder approaches and partnerships between the nutrition and food sectors. Also, the emerging situation with lifestyle related non-communicable diseases (NCD), also in low- and middle income countries, where mortality related to NCD is raising, supports the need for integrated approaches addressing the food sector and linking nutrition to agriculture.

The Southeast Asian regional policies and actions for linking nutrition to food security and other sectors are linked with global initiatives of which the Scaling-Up Nutrition (SUN) movement is central. SUN is promoting national coordinated initiatives and actions, mobilizing public and private stakeholders, to improve nutrition (2014). At country level, the SUN approach support governments to formulate national level action plans across agriculture, nutrition, health, and foods sectors, and transfer action to community level. Among the SMILING countries, the governments in Laos PDR and Indonesia committed their countries to the SUN movement in 2011, while Cambodia and Vietnam joint in 2014. One core focus of the SUN movement is to support those countries to ensure that the commitment to improve nutrition can be turned into action.

How can the food sector contribute to better nutrition? Promoting and securing dietary diversity is a key to better nutrition. A key contribution to better nutrition by the agriculture sector is to support access to a diverse diet through delivery of a diversity affordable, healthy and safe foods for a domestic market (Masset et al. 2012; Berti et al. 2004). Food-based solutions also includes the implementation of national food fortification programs to supply selected nutrients identified to be limited to achieve for vulnerable or major populations groups, based on the dietary pattern. Even if food security can be achieved and nutritious acceptable diets can be accessible to the majority of a population, there is high risk of bottlenecks to reach the required intake of specific micronutrients. Food fortification programs, mandatory or voluntary, require political decisions and implementation to reach its potential of improving status of specific micronutrients in populations (Hurrell et al. 2010; Dijkhuizen et al. 2013).

## Indicators for Micronutrient Deficiencies

Setting goals for reduction of micronutrient deficiencies rely on measurable indicators for the nutritional status of relevance. Indicators for micronutrient-related deficiencies of recognized public health significance of micronutrient deficiencies are given by WHO for anaemia (WHO 2011a), vitamin A (WHO 2011b) and iodine (World Health Organization 2001). Low haemoglobin level defines anaemia and relates to iron deficiency; low serum retinol or prevalence or reported night blindness are indicators for vitamin A deficiency; and urine iodine concentration is the recommended indicator for iodine status in populations. Zinc deficiency is recognised as a potential significant public health concern in many countries, but a reliable specific biological indicator is lacking for determining zinc deficiency in individuals (Hess et al. 2007). In Table 1, the key indicators for micronutrient deficiencies are listed. For zinc, serum zinc concentrations are regarded as a reliable marker for zinc deficiency only on population level. In populations with a prevalence of low serum zinc concentrations < 10%, zinc deficiency would not be considered a public health concern warranting national level programs. A prevalence of between 10 and 20% for low serum zinc values warrants further assessment of results, as the slightly elevated prevalence suggests that some segments of the population may be at high risk of zinc deficiency. Where the prevalence of low serum zinc values exceeds 20%, national programs may be considered along with further assessment to identify groups at risk. Other markers to support the evidence for zinc deficiency are dietary intake data and the prevalence of stunting in children < 5 years of age.

Not all indicators of micronutrient status reveal the real status, and some of the most commonly used markers are only proxy indicators (Wieringa et al. 2004, 2016). Anaemia is often used as an indicator for iron deficiency, even though anaemia can be multi-factorial, with many different possible causes, both nutritional as non-nutritional. WHO estimates

**Table 1** Indicators for nutritional status and the categories of prevalence for public health significance

| Indicator | Category of public health significance—percentage of population or population group | | | |
|---|---|---|---|---|
| | Normal/optimal | Mild | Moderate | Severe |
| Prevalence of anemia[a] | 4.9% or lower | 5.0–19.9% | 20–39.9% | 40% or higher |
| Prevalence of low serum retinol (< 0.7 µmol/L)[b] | 1.9% or lower | 2–9% | 10–19% | 20% or more |
| Night blindness in preschool-age children[c] | 0% | < 1% | ≥ 1 to < 5% | ≥ 5% |
| Night blindness in pregnant women[c] | ≥ 5% | | | |
| Low serum zinc concentrations (different cut-offs for different age groups/fasting or non-fasting subjects)[d] | < 10% | 10–20% | ≥ 20% | |
| Risk of low zinc intake (indicator for deficiency)[e] | | < 15% | 15–25% | ≥ 25% |
| Median urine iodine concentration (µg/L)[f] | 100–199 | 50–99 | 20–49 | < 20 |
| | Low | Medium | High | Very high |
| Stunting prevalence among C < 5y[g] | < 20 | 20–29 | 30–39 | ≥ 40 |
| Wasting prevalence among C < 5y[g] | < 5 | 5–9 | 10–14 | ≥ 15 |
| Underweight prevalence among C < 5y[g] | < 10 | 10–19 | 20–29 | ≥ 30 |

[a]WHO (2011a). Hemoglobin concentrations for the diagnosis of anemia and assessment of severity

[b]WHO (2011b). Serum retinol concentrations for determining the prevalence of vitamin A deficiency in populations (these cut offs do not apply for children under than 6 months)

[c]WHO 2009 Global prevalence of vitamin A deficiency in populations at risk 1995–2005 (World Health Organization 2009)

[d]Use of serum zinc concentration as an indicator of population zinc status (Hess et al. 2007)

[e]International Zinc Nutrition Consultative Group (IZiNCG) (2004)

[f]WHO, UNICEF, ICCIDD 2001 Assessment of iodine deficiency disorders and monitoring their elimination (2001)

[g]WHO database on child growth and malnutrition (WHO 2013)

that roughly 50% of the anaemia globally is caused by iron deficiency. However, recent evidence from Cambodia and other countries show that the contribution of iron deficiency to anaemia might be much lower (Wieringa et al. 2016; Petry et al. 2016). For other micronutrients, such as vitamin B1 (thiamine), no accepted cut-offs to indicate deficiency exist at present (Whitfield et al. 2017). Hence, even though biochemical indicators of micronutrient deficiency provide potentially the strongest possible evidence on whether a public health problem exists in a given country, policies cannot be based on biomarkers of micronutrient status alone.

## Methods

### Mapping Food Supplies

Data for national food supplies for the five SMILING countries were obtained from United States Food and Agriculture Organization (FAO)'s statistical database on food supplies (FAOSTAT). The database is available online at http://faostat.fao.org/. The most recent data for national food supplies the mapping period up to 2012 was accessed.

### Micronutrient Status and Interventions

The mapping of micronutrient status and interventions in the SMILING countries were conducted through a snowball identification method conducted through the national partner in the SMILING project: National Maternal and Child Health Center, Ministry of Health, Cambodia; National Institute of Public Health, Ministry of Health, Lao PDR; National Institute of Nutrition, Ministry of Health, Vietnam; SouthEast Asian Ministers of Education Organization (SEAMEO), Regional Centre for Food and Nutrition, Indonesia; and Institute of Nutrition, Mahidol University, Thailand. A protocol for mapping available and relevant data was developed among the SMILING partners for a semi-systematic identification of relevant information in the following categories:

- National surveys covering micronutrient and anthropometric status, 2002–2012
- National nutrition intervention programs, 1992–2012
- Any identified international or national initiatives/projects which compiled data and information on nutritional status and interventions (all time)

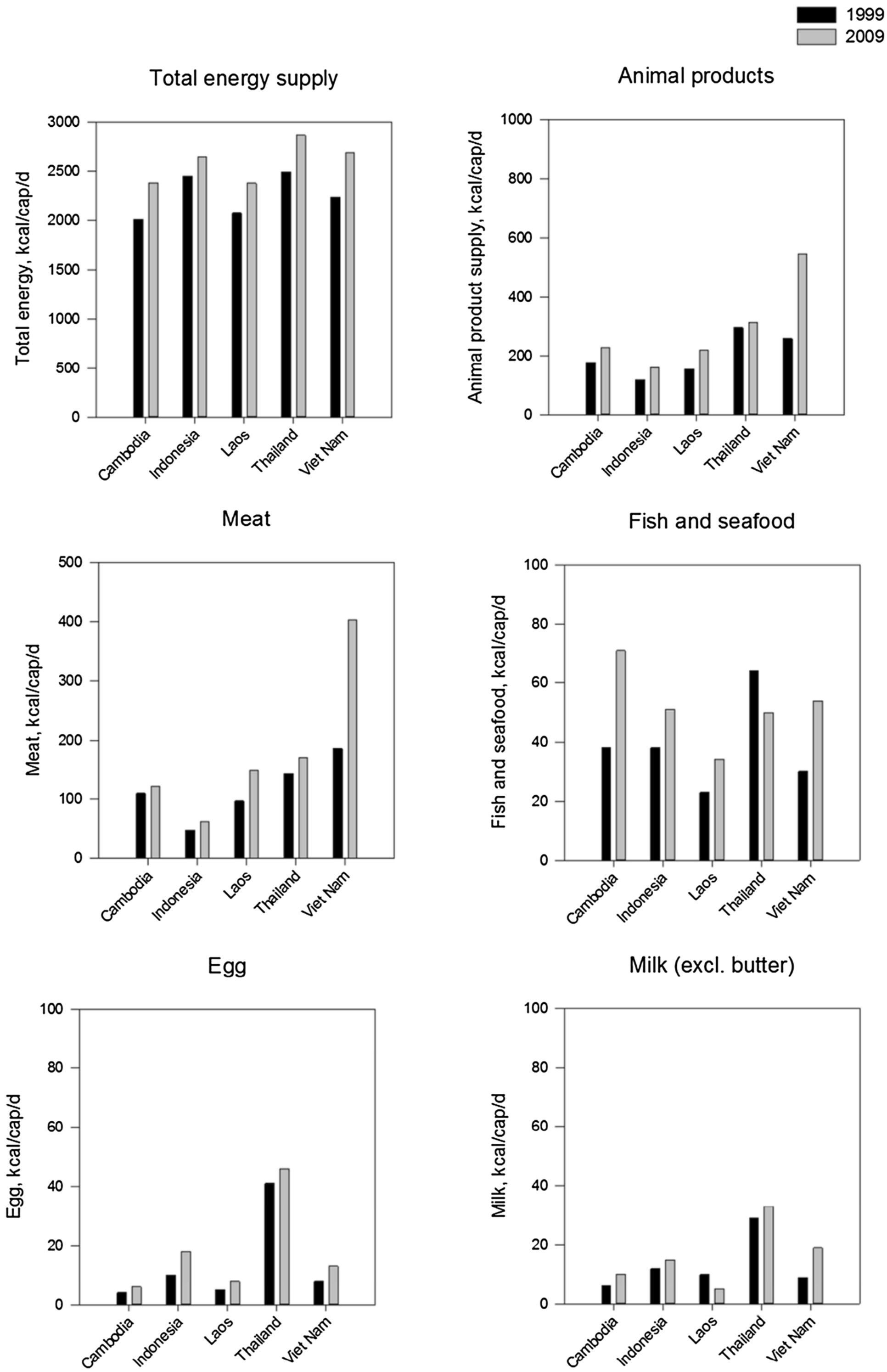


**Fig. 1** Total energy supply and supply from animal products (kcal/cap/d) development 1999–2009 in SMILING countries. Data from FAOSTAT (note differences in y-axis scales)

– Any identified national policies/strategies specifically targeted or specifically relevant for nutrition (all time)

## Results

### Food Supply Patterns

The food supply data on national level available from FAOSTAT showed marked differences between the countries (Supplementary Table 1). Data from Western Europe (a regional aggregate in FAOSTAT) is included for comparison. The dietary energy contribution from protein and fat was recalculated from the total supply as percentage of total dietary energy supply. The changes over time in the food supply patterns of time (1999–2009) are shown in Fig. 1. Among the most remarkable changes is the recorded increase in meat consumption in Vietnam.

### Available Data on Nutrition Status

Comparing nutritional status across countries rely on the availability of surveys providing reliable and comparable data. Surveys on key general nutritional indicators such as anthropometric measures for young children, expressed as rates of stunting and wasting are available with a frequency of 5 years or less in each country, while surveys on micronutrient status are much more scattered or not available.

Time points (year) of surveys and also the national representativeness of available information on micronutrient status varied greatly between countries. The information mapped from primary sources on nutritional status was compared with the WHO Nutrition Landscape Information System (NLIS) for the SMILING countries. It showed a delay in updates in NLIS information.

### Summary of Current Nutritional Status and Implemented Micronutrient and General Nutrition Interventions

The results of the mapping of the nutritional status and nutrition interventions with focus on micronutrients in the SMILING countries are summaries in the following sections. The summaries are extracted from compiled information across various surveys and information sources. Table 2 summarizes the latest available information on micronutrient deficiencies based on the data sources identified in Table 3. The prevalences can point at levels of public health significance (Table 1). The span in time between available data in each country, combined with underlying differences in sampling strategies etc limits the direct compare of the micronutrient situation across the region.

**Table 2** The latest available survey data on prevalence of micronutrient deficiencies and anaemia

| Information on | Cambodia | | Indonesia | | PDR Laos | | Thailand | | Vietnam | |
|---|---|---|---|---|---|---|---|---|---|---|
| | National | Sub-national | National | Sub-national | National | Sub-national | National | Sub-national | National | Sub-national |
| Vitamin A status | | | | | | | | | | |
| – Serum < 0.7 µm/L | 9.2% | – | – | 15% | 45% | – | – | – | 15/10%[a] | |
| – Night blindness | (1.8%)[a] | – | < 1% | – | – | – | – | – | – | |
| Iron | | | | | | | | | | |
| – Anaemia | 53.4%[b] | – | 28%[a] | – | 35% | – | 26% | – | 29%/9%[a] | |
| – Iron deficiency | 3.3% | 12%[a] | – | – | 18% | – | – | | | |
| Zinc (low serum) | 64.4% | 60%[b] | – | 32%[b] | – | – | – | 28–57%[b] | 81%/62%[b] | |
| Iodine | 66.2% <200 µg/L | – | > 200 µg/L | | 9% Goitre | – | > 200 µg/L | – | 83 µg/L (all) | – |

[a]Mild or moderate public health significance

[b]Severe public health significance

**Table 3** Most recent national and sub-national surveys in the period investigated (2002–2012) and updates up to 2014 on micronutrient status in SMILING countries

| Information on | Cambodia | | Indonesia | | PDR Laos | | Thailand | | Vietnam | |
|---|---|---|---|---|---|---|---|---|---|---|
| | National | Sub-national | National | Sub-National | National | Sub-national | National | Sub-national | National | Sub-national |
| Vitamin A status | | | | | | | | | | 2010cw |
| – Serum | 2014 CW | 2010[C] C | NA | 2007[a] C | 2000 cw | | 2003w | | | |
| – Night blindness | 2000 CW | | NA | 2007[a] C | 2000 w | | | | | |
| Iron | | | | | | | | | 2009cw | 2010cw |
| – Anaemia | 2014 CW | 2010[C] | NA | 2007[a] C | 2012 cw | | 2008w | | | |
| – IDA | 2014 W | CW | NA | NA | 2012 cw | | | | | |
| Zinc | 2014 c | 2010[d] C | NA | 2007[a] C | NA | NA | | 2006c | | 2010cw |
| Iodine | | 2014 c | 2007[b] C | | 2000c | | 2008cw | | | |

*C* children, *w* women, *NA* not available

Sources: Cambodia: CDHS (2010, 2014). Data for night-blindness from national survey in 2000; Indonesia: MoH (2007b); RISKESDAS (2014); Laos PDR: LSIS (2012); Thailand: IHPP (2013); Vietnam: Laillou et al. (2012); UNICEF (2010)

Nutrition interventions, with a specific focus on micronutrient interventions are summarized in Table 4. The mapping identified the intervention strategies decided on national level for implementation, along with any available information about the actual coverage (Tables 5, 6, 7).

### Cambodia

Vitamin A supplementation to children has been implemented in Cambodia for nearly two decades, and continues to be a part of the primary health system. National surveys on vitamin A were conducted in 2000 and 2014, and no data on vitamin A status was collected in the period investigated (2002–2012). The survey in 2014 showed a low of prevalence of vitamin A deficiency in children < 5 years of age (9.2%), while almost 30% of the children had marginal vitamin A status. The lack of intermediate data between 2000 and 2014 on changes in vitamin A status is a major limitation for the understanding of the impacts of micronutrient interventions. A small scale-study on multiple micronutrient powders (MNPs) in 2008–2010 indicates prevalence of low serum retinol of 1.1% at baseline (Jack et al. 2012). This survey was not national representative, and hence inconclusive. In women, the prevalence of vitamin A deficiency and marginal vitamin A status were 3.2% and 8.7% respectively, also indication that vitamin A deficiency appears to be less of a public health program than previously thought.

The findings from Cambodian Demographic and Health Survey (CDHS 2010, 2014) showed that anaemia is a critical public health problem in Cambodia, where more than half (55%) of children 6–59 months old are anaemic, with 28% mildly anaemic, 26% moderately anaemic, and 1% severely anaemic. The anaemia rate in children has not declined much from CDHS 2005 (62%) and CDHS 2000 (63%). In 2014, anaemia is highest among children age 9–11 months (83%), followed by children age 12–17 months (76.4%). Rural children are more likely (57%) to be anaemic than urban children (43%). Children of uneducated mothers and those residing in the poorest households are more likely than other children to be anaemic. For example, 64% of children in the lowest wealth quintile are anaemic, as compared with 43% of children in the highest wealth quintile. A comparison with the 2000 CDHS shows that the prevalence of anaemia has only declined by 12% in the past 14 years.

The CDHS 2014 also found that 45% of Cambodian women are anaemic. Proportion of women with anaemia in 2014 is also not reduced much compared with 2005 (47%) and 2000 (58%). Anaemia is more prevalent among women who are of high parity (more than four children), have little or no education, are pregnant, and live in poor households. Also, anaemia is higher among rural women (47%) than urban women (39%). 53% of pregnant women are also anaemic. The overall prevalence of anaemia has not decreased

**Table 4** Prevalences (year of survey) of stunting and wasting in children and chronic energy deficiency in women

| | Cambodia | Indonesia | PDR Laos | Thailand | Vietnam |
|---|---|---|---|---|---|
| Stunting[a] | 33% (2014) | 37% (2013) | 44% (2012) | 16% (2012) | 19% (2013) |
| Wasting[a] | 10% (2014) | 14% (2013) | 6% (2012) | 2% (2012) | 6% (2013) |
| CED[b] | 14% (2014) | 14% (2010) | 14% (2009) | 9% (2010) | 20% (2010) |

[a]Stunting (height-for-age Z-score (HAZ) < −2) and wasting (weight-for-height Z-score (WHZ) < −2) according to WHO growth standards for children age 0–59 months for Cambodia, Indonesia and Laos PDR, and age 1–5 years for Thailand and Vietnam

[b]CED: chronic energy deficiency body-mass-index (BMI) < 18.5 kg/m$^2$

Sources: CDHS (2014); RISKESDAS (2014); LSIS (2012); IHPP (2013); NIN (2014)

since the 2005 CDHS, raising questions on the aetiology of the anaemia (Wieringa et al. 2016).

The 2010 CDHS showed that 84% of children 6–59 months live in households using iodized salt. Differences in coverage were sizable by area of residence; 96% of urban children live in households with iodized salt, as compared with 82% of rural children. More than eight in ten women live in households with iodized salt. Women residing in Kampot/Kep (57%) are least likely to be living in households consuming iodized salt. Unfortunately, a survey in 2014 indicates that the coverage of iodized salt has strongly declined to 62% of the households using iodized salt (Laillou et al. 2015), most likely due to lack of provision of the iodine by international organizations to the salt industry and poor enforcement by government. As a result, the prevalence of low urinary iodine has increased, with > 60% of mothers and children having urinary iodine concentrations < 100 µg/L (Laillou et al. 2016).

In Cambodia, there were four micronutrient supplementation programs integrated into broader public health system, all targeted to women or children, and administered through antenatal, postnatal, and child health clinics. Two programs had national coverage, vitamin A supplementation (VAS) for children 6–59 months and iron/folic acid (IFA) supplementation for pregnant and postpartum women. Two programs were initiated in selected districts: weekly iron/folic acid supplementation (WIFS) for women of reproductive age, and MNPs for children 6–24 months. In 2002 the national vitamin A program for supplementation to children was extended to also cover supplementation of vitamin A to post-partum women (MoH 2007a). It is uncertain to which extend post-partum supplementation was implemented. The National Strategy for Food Security and Nutrition 2014–2018 did not include post-partum vitamin A supplementation (CARD 2014).

## Indonesia

In summary, Indonesia had no current national information of vitamin A deficiency amongst children and pregnant/lactating women. The latest national survey goes back to 1992–1993 and showed the national prevalence of xerophthalmia was 0.34%. The most current survey of vitamin A deficiency was the 'Study on micronutrient in Indonesia' covering vitamin A deficiency, anemia and zinc deficiency, conducted by Nutrition Research and Development Centre in 2007, in which data was available for 10 out of 33 provinces. The study shows that amongst children aged 6–59 months the prevalence of xeropthalmia was 0.13%, which indicated that vitamin A deficiency did not constitute a public health problem. The prevalence of children with serum retinol < 0.7 µmol/dL was 14.6%, which was below

**Table 5** Nutrition interventions mapped in the SMILING countries up to 2012: supplementation

| | Cambodia | | Indonesia | | Laos PDR | | Thailand | | Vietnam | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Intervention | Coverage | Intervention | Coverage | Intervention | Coverage | Intervention | Coverage | Intervention | Coverage |
| Vitamin A to children | To all children 6–59 mo through outreach services. May and November | 71% children in last 6 mo (2010) | High dose to all children 6–59 mo twice a year | 70% children (2010) | High dose twice a year to children 6-59 mo | 59.1% children (2011-2012) | None | | To all children 6–36 mo twice a year | Not known |
| Vitamin A to post-partum women[a] | To all women within 6 weeks of delivery | 45% (2010) | To all women within 40 days of delivery | 47% (2007) | To all post-partum women | 17.9% (2006) | To post-partum women | 18% (2009) | LW within the first month after delivery | Not known |
| Iron and folic acid to women | 90 tablets during pregnancy and 45 tablets post-partum | 57% of PW taking min. 90 tablets 45% post-partum W received tablets (2010) | 90 tablets during pregnancy | 29% PW received tablets (2007) | Weekly to WRA 15–49 years) | 38.5% only in three southern provinces: Savannakheth, Saravan, Attapu (2010–2012) | Iron/folate tablets to PW and iodine tablets to PW and LW | Phased out. replaced by 'triferdine'* | Iron/folate tablets or MMN daily to PW to 1 mo after delivery | Only one mountainous district |
| | Weekly Iron/folic acid for WRA | 14% WRA in 6 districts during last month | – | | | | Iron weekly to WRA in the workplace | Phased out replaced by 'triferdine'* | Weekly to WRA (15–35 years), 16 weeks/year | Only one mountainous district |
| MMN to children | MMN powder, daily supplement to children 18–24 mo | 37% in 4 of 37 operational districts | MMN powder for complementary foods | Unknown. Only in test area | MMN (MixMe) to children 6–59 mo | 31.4% in three provinces: Saravan (2010–2012), Attapu (2010–2011), and Sekong (2009) | – | | – | |
| MMN to women | – | | MMN powder distributed to PW | Unknown. Only in test area | – | | MMN 'triferdine' to PW through 6 weeks post-partum | Indications of > 90% coverage. Formal data lacking | MMN daily to PW from 8–12 weeks of pregnancy to 1 mo after delivery | Only implemented in one mountainous district |

**Table 5** (continued)

| | Cambodia | | Indonesia | | Laos PDR | | Thailand | | Vietnam | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Intervention | Coverage | Intervention | Coverage | Intervention | Coverage | Intervention | Coverage | Intervention | Coverage |
| Iron to children | – | | – | | Weekly iron-folic acid to school children | 66.4–95.8% in three southern provinces: Savannakhet, Saravan, Attapu (2010–2012) | Iron, weekly to school children in "health promoting schools" program | Selected areas | | |
| Zink | Zinc to children < 5 years with diarrhea | 2% of all children < 5 years have received zinc | Zinc to children < 5 years with diarrhea | Only in test area | Zinc to children < 5 years with diarrhea | 5% of all children | | | | |

Notes and abbreviations follow Table 7

the International Vitamin A Consultative Group (IVACG) definition of public health problem.

For iron deficiency, the 2007 survey in ten provinces showed that the prevalence of iron deficiency anemia amongst children < 5 years of age was 26.3%, which indicates a moderate public health problem (≥ 20%). The prevalence of low serum zinc, indicating zinc deficiency, was 31.6%.

Indonesia Basic Health Research 2007 (RISKESDAS 2007) showed that iodine deficiency is not a public health problem among children 6–12 years old in Indonesia. The proportion of children with urinary iodine excretion (UIE) < 100 µg/L was 12.9%, well below the 50% considered to indicate a public health problem of iodine deficiency. The median value of UIE among children in 30 cities/districts in Indonesia was 224 µg/L, which was above the recommended sufficiency value. There were 2 cities where the median value of UIE was above 300 µg/L, indicating risk of excess intake of iodine. The coverage of iodized salt is 62.3% in 2007. However, study also shows that actually only 24.8% of salt used in the households contains the prescribed iodine level in the salt (30–80 ppm).

The micronutrient interventions applied at national scale were vitamin A capsule supplementation for children 6–59 months, iodized salt for all households, and iron-folic acid tablet for pregnant women. Postpartum vitamin A supplementation was under consideration to be with-drew following the WHO recommendation. The fortification of wheat flour with micronutrient including iron and zinc is mandatory but it lacks monitoring and evaluation for coverage and impact. Other micronutrient interventions which had been tested but not yet implemented at national scale include inclusion of 10-day zinc supplementation in the treatment of diarrhea; multi-micronutrient powder for complementary foods, multi-micronutrient supplementation for pregnant women, vitamin A-fortified cooking oil, fortified biscuits and noodles for children and pregnant/lactating women, fortified complementary foods, and rice fortification only for rice-for-the poor. Those interventions had not been put into the national monitoring scheme.

## Laos PDR

In summary, recent national data on micronutrient status were lacking, and no updated surveys have been conducted since the mapping. Available data indicate that anaemia is a major nutritional disorder in Laos PDR. The prevalence of anaemia among children 6–59 months of age was 41% in 2006 (MICS 2006), indicating a severe public health problem. Data from a national nutrition survey in 2005 indicated that half of the anaemia was due to iron deficiency. The prevalence was 63% among children aged 6–23 month. A later sub-national survey on anaemia prevalence in four provinces

**Table 6** Nutrition interventions mapped in the SMILING countries up to 2012: fortification

| | Cambodia | | Indonesia | | Laos PDR | | Thailand | | Vietnam | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Intervention | Coverage | Intervention | Coverage | Intervention | Coverage | Intervention | Coverage | Intervention | Coverage |
| Iodized salt | Mandatory | 84% HH using iodized salt (2010) | Mandatory | 84% of HH Iodized salt > 30 ppm $KIO_3$ | Mandatory | 79.5% Iodized salt coverage (presence of iodine in salt in HH) | Mandatory, also for salt for fish- and soy sauces, salt brine for cooking, and for processed products | 47% HH coverage (MICS 2006) (lowest in North East, 23%) | Mandatory | 86% HH using iodized salt |
| Other fortified foods | | | Vit A: cooking oil | Only in test area | | | Mandatory fortification with Vit A of sweetened condensed milk | Unknown. Sweetened milk is not recommended for children | Vit A: cooking oil | Not assessed |
| | | | MMN: biscuits and noodles; compl. foods | Only in test area | | | MMN: voluntary fortification of instant noodle soup mix with iron, vit A and iodine | 60–70% of instant noodles available in market are fortified. | MMN: various foods | Not assessed. Only in test area |
| | | | Rice fortification: 'rice-for-the poor' program | Only in test area | | | Iodinated water in school in remote areas | Phasing out (replaced by iodized salt) | Rice fortification: 'rice-for-the poor' program | Not assessed |
| | | | | | | | | | Voluntary iron-fortified fish sauce | Nor assessed |

Notes and abbreviations follow Table 7

**Table 7** Nutrition interventions mapped in the SMILING countries up to 2012: other interventions

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Education | | | | | | | | | | |
| | Actions on infant and child feeding practice and maternal nutrition | 70% reported excl. breastfeeding at 6 mo[b] | Breastfeeding promotion | 29.3% early breastfeeding initiation 15.3% excl. breastfeeding to 6 mo | Promotion breastfeeding education (mass campaigns, health system, NGOs) | 40.4% exclusive breastfeeding to 6 mo | Nutrition education on breast-feeding and complementary feeding | 31.1% breastfeeding until 3 mo 7.0% excl. breastfeeding until 6 mo | Nutrition education for dietary diversification (public campaign) | Un-known |
| | | | | | | | Campaign to reduce sugar consumption | Not assessed | | |
| Deworming | | | | | | | | | | |
| | School and clinics | 57% children dewormed last 6 mo 45%[a] WRA took deworming during last pregnancy | | | Various programs | 94% children 6–59 mo dewormed | | | | |
| Foods and diets | | | | | | | | | | |
| | Promotion of homestead food production and nutrition education | Unknown | | | Promotion of dietary diversity through promotion of home gardening and nutrition education | Not assessed | Milk powder for women not gaining adequate weight during pregnancy, and for HIV+ mothers | Not assessed | 'VAC system': Model to improve the household dietary intake focusing on local vitamin A-rich food | Not assessed |
| | | | | | Received cash/food to attend health facility[b] | 9.6% | Provision of lunch and milk in preschool and kindergarden | Not formally assessed school milk estimated close to full coverage (age 3–12 years) | | |
| | | | | | Severly acute malnourished (SAM) children received RUTF | 13.1% | Agriculture-related lunch program in preschool and primary school | Not assessed | | |

*mo* months of age, *MMN* multimicronutrients, *PW* pregnant women, *LW* lactating women, *WRA* women in reproductive age, *HH* households

Cambodia: Cambodia Demographic and Health Surveys (CDHS) 2010 and 2014; Information obtained from National Nutrition Program, Ministry of Health, Cambodia

Indonesia: Indonesia Basic Health Research (Riskesdas 2007; Riskesdas 2010), National Institute of Health Research and Development (NIHRD), Ministry of Health; Indonesia Demographic and Health Survey, 2007

Laos PDR: Lao PDR—Multiple Indicator Cluster Survey 2006; National Nutrition Survey, 2006; Baseline Survey for the Mother & Young Child Nutrition Security Initiative- 2011–2012; National Maternal and child Nutrition Survey (MICS3-NNS) Report, 2006; Lao Social Indicator Survey (LSIS), 2011–201;. Nutrition assessment in flood and Typhoon Ketsana areas in nine provinces, 2009; Assessment WIFS report 2012

Thailand: National Statistics Office, Key statistics of Thailand. 2011; Winichagoon (2013)

Vietnam: National Nutrition Strategy, 2001—2010 and 2010–2020

[a]Vitamin A supplementation to post-partum women is no longer recommended

[b]CDHS reports 'exclusive breastfeeding', but it is not declared if the survey methodology comply with WHO guidelines for assessing exclusive breastfeeding

in 2011–2012 survey showed a prevalence of 28.8% among children age 6–59 months and 31.9% among non-pregnant women of reproductive age, indicating improvement (LSIS 2012). However, prevalence of anaemia in children is still of moderate public health significance and interventions are needed.

The micronutrient interventions in place were iron supplements to pregnant women during antenatal care visits, and weekly iron-folate supplementation is also provided to WRA women 12–49 years old in few selected areas. Vitamin A supplementation is recommended to children aged 6–59 months, and to women who seek antenatal care. Despite these efforts, the coverage of vitamin A supplementation of children is relatively low, 59.1%.

Iodised salt is mandatory with an indicated coverage of around 80.0% of household using iodized salt. The iodine content in salt at household level is unknown. The coverage tends to decrease since 2006, indicated renewed efforts to ensure high coverage of iodised salt is required.

There is no data available on zinc and vitamin D status.

Laos PDR has received support from the global partnership 'REACH', jointly established by the United Nations Food and Agriculture Organization (FAO), World Health Organization (WHO), United Nations Children's Fund (UNICEF) and the World Food Programme (WFP), to support governments in nutritional planning. In 2011, the country has also declared commitment to joining the 'Scaling-Up-Nutrition' (SUN) movement.

### Thailand

The last national vitamin A survey in 2003 indicated that the problem had largely been eliminated (information form Bureau of Health) and since then no surveys had been conducted. No national data for iron and zinc deficiency are available. More recent the focus has shifted to other potential deficiencies of potential public health concern such as vitamin D, as well as a renewed attention on iodine deficiency.

In summary, Thailand had—unlike all other SMILING countries—no history of a national vitamin A supplementation program. A government regulation from 1993 requires that the sweetened condensed milk must be fortified with vitamin A, but sweetened milk is at present not recommended for children. From 1996, the triple fortified (iron, iodine, and vitamin A) instant noodle soup mix was launched in the market on voluntary basis, and at present 70–80% of the noodles are fortified with about one-third the Recommended Dietary Allowance for vitamin A (267 µg RE), iodine (50 µg), and iron (5 mg) per serving (Winichagoon 2013).

For iron, iron/folate tablets have been distributed to pregnant women through ANC and weekly iron supplementation to schoolchildren was launched under the "heath promoting schools" program in 2000 (Thurlow et al. 2006). Additionally, weekly iron supplementation to reproductive age women was launched in the workplace. At present, iron and iron/folate supplementation is being replaced by the triple supplement 'triferdine' (iron, folate and iodine supplement). The distribution coverage is estimated indirectly, mainly by estimating the coverage of antenatal-care clinics. There is no formal reporting system on the number of women receiving tablets or the actual number of tablets consumed.

Combined iron and zinc supplementation has been tested in infants (Wasantwisut et al. 2006). There is no national program for controlling zinc deficiency in Thailand.

Over time, several national programs for IDD control have been implemented in Thailand including Universal Salt Iodization (USI), iodine supplementation in pregnant women, iodinated water in school children, and surveillance system for program monitoring and evaluation. The legislation for the USI indicated that edible salt is to be constituted with iodine in the concentration of 20–40 mg/kg of salt. In addition, fish sauce, salt brine and seasoning products of soybeans are to be constituted with iodine in the concentration of 2–3 mg/l of products. In remote areas, iodinated water (200 µg/l) for primary school children has been implemented, but is phased out and replaced by iodized salt in school lunch.

Supplementation approach was implemented in 2011, integrating iron, folate and iodine ('triferdine'). Pregnant women in community health centres receive a daily supplement tablet. There is a cyclical monitoring program of urinary iodine concentration for school-age children and pregnant women (15 provinces/year for 5 years). After implementing iodine supplementation, urinary iodine concentrations are also collected from hospitals, and additional monitoring program of pre-school children and elderly was conducted. In addition, the screening of neonatal serum concentration of thyroid stimulating hormone (TSH) for congenital hypothyroidism is used as a monitoring tool to assess the iodine nutrition of populations.

Household iodized salt is monitored for iodine content for assessing household coverage of adequately iodized salt. Data on iodized salt from salt testing may not reflect the iodized salt consumption in the households in terms of frequency and amount consumed.

For food fortification, instant noodles were identified as a potential vehicle for fortification due to high consumption and widely available throughout the country. The soup mix of the instant noodle has been voluntary triple fortified (iron, iodine, and vitamin A) since 1996 under the collaboration of academic, public, and private sectors. This fortified noodle soup mix contains about one-third the Recommended Dietary Allowance for vitamin A (267 µg RE), iodine (50 µg), and iron (5 mg). Coverage has reached 70–80% of the available instant noodle products in the market. A cross-sectional survey conducted in a northeast province in 2001 indicated that the soup mix was added during cooking. This process may cause the nutrient loss during heating.

### Vietnam

In summary, recent information of micronutrient status of the Vietnamese population was more available compared to other SMILING countries at the time of the mapping due to updated national surveys in 2009 and 2010. For vitamin A, sub-clinical vitamin A deficiency in children is still in 2009 moderate level in some areas (14.2% nationwide). The results of the survey in 2009 showed that clinical vitamin A deficiency (xerophtalmia) had disappeared. Sub-clinical vitamin A deficiency in breastfeeding mothers remains a concern, with rates of low vitamin A in breast milk up to 35%. A recent study undertaken in Vietnam indicated that 1.6% of WRA suffered from VitA deficiency (Laillou et al. 2012). Comparing between the ecological areas, three regions shows prevalence of vitamin A deficiency among children < 5 years significantly higher than the mean prevalence for the nation: Central highlands (20.9%), the Northern mountainous area (19.40%) and Mekong river Delta (17.0%). This supports that intervention efforts can be differentiated to target the most vulnerable regions and populations groups.

A survey from 2009 indicated that the prevalence of anaemia has decreased in all regions compared to 1995, but still remained at moderate to mild levels of public health significance for children and women. The survey on anaemia and sub-clinical vitamin A deficiency (NIN 2009) showed a higher prevalence of anaemia, 29.2% in children < 5 years, 36.5% in PW and 28.5% in WRA. The same survey showed prevalence of low iron store for children, PW and WRA (49%, 53% and 28%, respectively). A more recent survey indicate prevalences of iron deficiency of 12.9% for children aged 6–75 months (plasma ferritin < 12 µg/L) and 13.7% for WRA (plasma ferritin < 15 µg/L) (Laillou et al. 2012). The same survey indicated vitamin D deficiency to be of concern in children and WRA (Laillou et al. 2013). The availability of survey data within a short period of time (2009–2012) with considerable different indications of prevalence of anaemia indicate that standardization of sampling for comparison over time may be needed, as well at that annual or seasonal fluctuations may occur, following ecological exposures. Big discrepancies are observed between areas and provinces: the two mountainous areas (Northwest and Northeast) are the most affected by anaemia.

For zinc, the available data on serum zinc as indicator for zinc deficiency from the same surveys indicate that a significant public health concern of zinc deficiency. There are no universal zinc interventions, but supplementation of zinc to children suffering from diarrhea, as a part of the treatment. The coverage of zinc supplementation is low and does not reach a level where is contribute to prevention of deficiency.

Iodine deficiency disorders have been eliminated since 2005, and data for urinary iodine do not indicate a public health problem. However, the level of urinary iodine and the coverage of qualify iodized salt for prevention tends to decrease (from iodized salt coverage in households in 2005 of 91.9%, going down to 69.5% in 2009).

Of micronutrient interventions, vitamin A supplementation is targeted young children aged 6–36 months with biannual distribution,and for mothers within 1 month after birth. Also children with pneumonia, measles and prolonged diarrhea are offered vitamin A supplementation. In vulnerable areas with elevated risk of micronutrient deficiencies, children are supplemented up to the age of 5 years. Supplementation programs are complemented by other interventions for increased vitamin A intake, such as education programs for increasing consumption of vitamin A rich foods and vitamin A fortification on foods such as rice, vegetable oil and other food.

For anaemia and iron deficiency, the nutritional anaemia prevention program focused on nutrition education and communication: diversified dietary intake, concentrated in local food sources and communication for pregnant women and the risk mothers to buy iron tablets by their own money in the most provinces across the country. Fortification with iron in fish sauce was approved by government and it was implemented 3 years ago. This is a technical solution to contribute to the prevention of iron-deficiency anemia in large-scale. A national programs for iron/folic acid supplementation for women 15–35 years of age and pregnant women and lactating mothers in the whole country has not been implemented due to limited resources.

There have been increasing focus and activities in health and nutrition communication and education in the last 5 years, also to reach to the grass-root level.

## Discussion

### Food Supply Patterm

An overall nutritional profile of the national food supply available for the populations in the five 'SMILING countries' in Southeast Asia can be argued to be reflected in the contribution from protein and fat to the total dietary energy supply. To compare, the aggregated dietary supply for Western Europe indicates a fat energy supply of around 40% and protein supply of around 12% (Supplementary Table 1). Though representing some variation across European dietary cultures, these fat and protein shares are remarkable comparable to values from directly assessed consumption data from

European countries (Linseisen et al. 2009). For the SMILING countries in the Southeast Asian region, the protein E% of the food supply is around 10–12 E% in all countries (also Supplementary Table 1). From a nutritional view, protein supply of 10–15 E% is sufficient to meet requirement, if supplied form a diverse diet with a share of animal protein. Across the SMILING countries, two-third of the protein supply is from vegetal sources, and one-third from animal sources. This is contrasting the western European food supply where more than half of the protein is contributed from animal protein.

From a nutritional point, a dietary fat intake of 20–30 E% is recommended as favorable for healthy adults. Excess fat intake will, in addition to increasing the risk of overweight and obesity, also contribute to diluting the supply of micronutrient intake by increasing the energy density of the diet, and hence lowering the micronutrient density contributed from micronutrient dense foods such as fruits, vegetables and lean meat/fish. The food supply data shows that the fat supply in the SMILING countries ranged from 14 E% in Laos PDR and Cambodia to 27 E% in Thailand—well below the 40 E% for Western Europe.

Recognizing that food supply data are providing averages figures across population- and socioeconomic groups, and not as such evidential for consumption, the supply data provides a general picture of the nutritional environment of the national food system, indicating the dietary background for any food-based intervention which may be aimed for improving nutritional status in the populations. The supply data indicates that available dietary fat may be limited in some of the countries, while total protein availability appears less divergent from the dietary requirements on population level.

For the changes in food supply pattern over time (Fig. 1), there were a trend of increase in total dietary energy supply per capita in all countries. The share supplied from animal foods is of particular important for the supply of micronutrients (Dror and Allen 2011). Thailand had a stagnant supply from animal foods over the decade investigated, while Vietnam had the most pronounce change by doubled the supply over the decade. The lowest supply of animal foods is reported from Indonesia. When disaggregating the supply into major animal food groups—meat, fish and seafood, egg and milk—major differences between the countries were seen. Fish and seafood supply had increased in all countries except Thailand, with Cambodia experiencing the steepest increase. It is notable that egg and milk supplies were very low in especially Cambodia and Laos PDR. Even Thailand had slightly higher supplies than the other SMILING countries; the per capita supply of milk in Thailand is around 10% of the supply in Western Europe.

Recognizing that food supply data are limited in the interpretation of actual consumption, the food supply patterns on national levels supported an overall picture that the food systems are in rapid development. The food supply and dietary pattern of the populations impacts on any nutrition intervention implemented, and the should be integrated in the policies.

## Micronutrient Status

The mapping of data on micronutrient status clearly demonstrated that the lack of recent, frequent and comparable data on micronutrient status. Micronutrient surveys are relatively costly and the methodology and interpretation have developed over time. This explains the lack of comparable data availability. However, this lack of consistent and comparable data on the development of the micronutrient status on population level also hinder that policy makers are informed about the real impact of the investments in micronutrient interventions on public health outcomes. While each national government and responsible implementing organisation have an interest in information which could document the impact of nutrition interventions over time, a stronger regional information sharing and coordination of survey methodology could support a stronger base of evidence for the needs and impacts of micronutrient interventions. The scattered data available indicated that micronutrient deficiencies persist as a public health problem, but the complexity is high. While vitamin A deficiency was highly prevalent a two decades ago, the modernization and shifting lifestyles supported by supplementation programs might switch the concern to other nutrients such as zinc and vitamin D. Anaemia is a persistent problem in the region, but the underlying causes appears to be more complex than to mainly being mediated by iron deficiency.

## Micronutrient Interventions

The micronutrient interventions mapped for the period 2002–2012 showed that the micronutrient interventions to be implemented in national programs in Cambodia, Laos PDR, Indonesia and Vietnam were similar for the micronutrient supplementation to children and women (vitamin A supplementation to children and iron-folic acid tablets to pregnant women, and to some extend to WRA), while Thailand had targeted the same nutritional problems with different approaches. Vitamin A was never supplemented to children in Thailand, while national fortification programs of specific food (condense milk and noodles) had been implemented much earlier, starting the 1970s. All countries had a formulated policy of supplementing post-partum women, but these programs were interfered with the recommendation by WHO that such supplements appeared to have no effect on vitamin A status of the new-born.

Programs for distribution of micronutrient powders had also been implemented children or women in Cambodia, Laos PDR, Indonesia and Vietnam, though none of the programs had reached national coverage. Thailand had developed a supplement with three nutrients—iron, folate and iodine—for women, based on identified deficiencies.

Food fortification was implemented in all countries, with iodized salt as the global strategy, and various programs for iron and vitamin A fortification. Iodized salt was mandatory, along with mandatory vitamin A fortification of condensed milk in Thailand, while other programs were voluntary and based on agreements with the industry. Aside for iodized salt, the fortification effort lacked impact assessments. While fortification is a highly promising strategy, the implementation requires political decisions, and efficient control of the actual delivery of fortified products must be in place.

Nutrition education had focus on breastfeeding promotion and improved complementary feeding. The breastfeeding practices appeared to be favourable among the SMILING countries, with Thailand being challenged with a shorter duration than the other countries. The exact duration of exclusive breastfeeding was not precisely assessed, leading for example to the report of 70% exclusive breastfeeding in Cambodia, which was assumed to be overestimated.

## Conclusion

The conclusion of this mapping of micronutrient status (2002–2012) and nutrition interventions (1992–2012) showed that public health concerns with regard to micronutrient deficiencies exist. However, for interventions implemented to improve micronutrient status the evidence of effect was weak because of lack of nationally representative data collected with a frequency which could show changes over relevant time periods matching the implemented intervention strategies. Improvement of intervention programs to efficiently reduce or eliminate micronutrient deficiencies requires more systematic monitoring and evaluation of effects of interventions in order to identify best practices and inform policy makers.

## References

Berti, P. R., Krasevec, J., & FitzGerald, S. (2004). A review of the effectiveness of agriculture interventions in improving nutrition outcomes. *Public Health Nutrition, 7*, 599–609.

Black, R. E., Victora, C. G., Walker, S. P., Bhutta, Z. A., Christian, P., de Onis, M., et al. (2013). Maternal and child undernutrition and overweight in low-income and middle-income countries. *Lancet, 382*, 427–451.

Burlingame, B., Charrondiere, R., & Halwart, M. (2006). Basic human nutrition requirements and dietary diversity in rice-based aquatic ecosystems. *Journal of Food Composition and Analysis, 19*, 770.

CARD. (2014). *National strategy for food security and nutrition, Cambodia*. Phnom Penh, Cambodia: Council for Agricultural and Rural Development (CARD).

CDHS (Cambodian Demographic and Health Survey 2010). (2010). National Institute of Statistics, Ministry of Planning, Phnom Penh, Cambodia.

CDHS (Cambodian Demographic and Health Survey 2014). (2015). National Institute of Statistics, Ministry of Planning, Phnom Penh, Cambodia.

Deitchler, M., Mason, J., Mathys, E., Winichagoon, P., & Tuazon, M. A. (2004). Lessons from successful micronutrient programs. Part I: Program initiation. *Food and Nutrition Bulletin, 25*, 5–29.

Dijkhuizen, M. A., Wieringa, F. T., Soekarjo, D., Van, K. T., & Laillou, A. (2013). Legal framework for food fortification: Examples from Vietnam and Indonesia. *Food and Nutrition Buletin, 34*, S112–S123.

Dixon, J., Banwell, C., Seubsman, S. A., Kanponai, W., Friel, S., & Maclennan, R. (2007). Dietary diversity in Khon Kaen, Thailand, 1988–2006. *International Journal of Epidemiology, 36*, 518–521.

Dror, D. K., & Allen, L. H. (2011). The importance of milk and other animal-source foods for children in low-income countries. *Food and Nutrition Bulletin, 32*, 227–243.

Hess, S. Y., Peerson, J. M., King, J. C., & Brown, K. H. (2007). Use of serum zinc concentration as an indicator of population zinc status. *Food and Nutrition Bulletin 28*(Supplement 3), 403S–429S.

Hurrell, R., Ranum, P., de Pee, S., Biebinger, R., Hulthen, L., Johnson, Q., et al. (2010). Revised recommendations for iron fortification of wheat flour and an evaluation of the expected impact of current national wheat flour fortification programs. *Food and Nutrition Bulletin, 31*, S7–S21.

IHPP. (2013). *Thailand multiple indicator cluster survey 2012. MICS. International Health Policy Program (IHPP)*. Bangkok: National Statistical Office (NSO), UNICEF, Ministry of Public Health (MoPH). National Health Security Office (NHSO), Thai Health Promotion Foundation.

IZiNCG. (2004). International Zinc Nutrition Consultative Group (IZiNCG) technical document. Assessment of the Risk of Zinc Deficiency in Populations. *Food and Nutrition Bulletin 25* (Supplement 2), 130S–162S.

Jack, S. J., Ou, K., Chea, M., Chhin, L., Devenish, R., Dunbar, M., et al. (2012). Effect of micronutrient sprinkles on reducing anemia: A cluster-randomized effectiveness trial. *Archives of Pediatrics & Adolescent Medicine, 166*, 842–850.

Laillou, A., Mam, B., Oeurn, S., & Chea, C. (2015). Iodized salt in Cambodia: Trends from 2008 to 2014. *Nutrients, 7*, 4189–4198. https://doi.org/10.3390/nu70641897.

Laillou, A., Pham, T. V., Tran, N. T., Le, H. T., Wieringa, F., Rohner, F., et al. (2012). Micronutrient deficits are still public health issues among women and young children in Vietnam. *PLoS ONE, 7*, e34906.

Laillou, A., Sophonneary, P., Kuong, K., Hong, R., Un, S., Chamnan, C., et al. (2016). Low urinary iodine concentration among mothers and children in Cambodia. *Nutrients, 8*, 172. https://doi.org/10.3390/nu8040172.

Laillou, A., Wieringa, F., Tran, T. N., Van, P. T., Le, B. M., Fortin, S., et al. (2013). Hypovitaminosis D and mild hypocalcaemia are highly prevalent among young Vietnamese children and women and related to low dietary intake. *PLoS ONE, 8*, e63979.

Linseisen, J., Welch, A. A., Ocke, M., Amiano, P., Agnoli, C., Ferrari, P., et al. (2009). Dietary fat intake in the European Prospective Investigation into Cancer and Nutrition: results from the 24-h dietary recalls. *European Journal of Clinical Nutrition, 63*(Suppl 4), S61–S80.

LSIS. (2012). *Lao Social Indicators Survey (LSIS)*. Vientienne, Laos PDR: National Statistical Centre, Ministry of Planning and Investment and National Institute of Public Health, Ministry of Health.

Masset, E., Haddad, L., Cornelius, A., & Isaza-Castro, J. (2012). Effectiveness of agricultural interventions that aim to improve nutritional status of children: Systematic review. *British Medical Journal, 344*, d8222. https://doi.org/10.1136/bmj.d8222.

McDonald, C. M., McLean, J., Kroeun, H., Talukder, A., Lynd, L. D., & Green, T. J. (2015). Correlates of household food insecurity and low dietary diversity in rural Cambodia. *Asia Pacific Journal of Clinical Nutrition, 24*, 720–730.

MICS. (2006). *Thailand - Multiple Indicator Cluster Survey 2005–2006*. Bangkok, Thailand: National Statistical Office of Thailand.

MoH. (2007a). *National vitamin A policy guidelines*. Phnom Penh, Cambodia: Ministry of Health (MoH), National Nutrition Program, National Maternal and Child Health Centre.

MoH. (2007b). *Study on micronutrients in Indonesia*. Indonesia: Nutrition Research and Development Centre, Ministry of Health (MoH). Report.

Muslimatun, S., & Wiradnyani, L. A. (2016). Dietary diversity, animal source food consumption and linear growth among children aged 1–5 years in Bandung, Indonesia: A longitudinal observational study. *British Journal of Nutition, 116*(Suppl 1), S27–S35.

NIN. (2009). *Vietnam micronutrient deficiency survey*. Vietnam: National Institute of Nutrition (NIN), Ministry of Health, Global Alliance for Improving Nutrition (GAIN) and Institute de Research pour le Développement (IRD).

NIN. (2014). *Nutrition surveillance profiles 2013*. Hanoi, Vietnam: National Institute of Nutrition (NIN), UNICEF and Alive & Thrive. Ministry of Health.

Petry, N., Olofin, I., Boy, E., Donahue, A. M., & Rohner, F. (2016). The effect of low dose iron and zinc intake on child micronutrient status and development during the first 1000 days of life: A systematic review and meta-analysis. *Nutrients, 8*(12), E773.

RISKESDAS. (2007). *National report on basic health research, Indonesia*. Jakarta, Indonesia: Ministry of Health and National Institute of Health Research and Development.

RISKESDAS. (2010). *National report on basic health research, Indonesia*. Jakarta, Indonesia: Ministry of Health and National Institute of Health Research and Development.

RISKESDAS. (2014). *National report on basic health research, Indonesia*. Jakarta, Indonesia: Ministry of Health and National Institute of Health Research and Development.

SUN. (2014). Retrieved September 05, 2018, from http://scalingupnutrition.org/about.

Thurlow, R. A., Winichagoon, P., Pongcharoen, T., Gowachirapant, S., Boonpraderm, A., Manger, M. S., et al. (2006). Risk of zinc, iodine and other micronutrient deficiencies among school children in North East Thailand. *European Journal of Clinical Nutrition, 60*, 623–632.

UNICEF. (2010). *Vietnam general nutrition survey 2009-2010*. Hanoi, Vietnam: UNICEF and National Institute of Nutrition (NIN), Ministry of Health.

Wasantwisut, E., Winichagoon, P., Chitchumroonchokchai, C., Yamborisut, U., Boonpraderm, A., Pongcharoen, T., et al. (2006). Iron and zinc supplementation improved iron and zinc status, but not physical growth, of apparently healthy, breast-fed infants in rural communities of northeast Thailand. *Journal of Nutrition, 136*, 2405–2411.

Whitfield, K. C., Smith, G., Chamnan, C., Karakochuk, C. D., Sophonneary, P., Kuong, K., et al. (2017). High prevalence of thiamine (vitamin B1) deficiency in early childhood among a nationally representative sample of Cambodian women of childbearing age and their children. *PLoS Neglected Tropical Diseases, 11*, e0005814.

WHO. (2001). *Assessment of iodine deficiency disorders and monitoring their elimination: a guide for programme managers* (2nd ed.). Geneva: World Health Organization (WHO); International Council for Control of Iodine Deficiency Disorders; and UNICEF.

WHO. (2009). *Global prevalence of vitamin A deficiency in populations at risk 1995–2005. WHO global database on vitamin A deficiency*. Geneva: World Health Organization (WHO).

WHO. (2011a). *Haemoglobin concentrations for the diagnosis of anemia and assessment of severity. Vitamin and mineral nutrition information system*. Geneva: World Health Organization (WHO-NMH-NHD-MNM/11.1-VMNIS).

WHO. (2011b). *Serum retinol concentrations for determining the prevalence of vitamin A deficiency in populations. Vitamin and mineral nutrition information system*. Geneva: World Health Organization (WHO/NMH/NHD/MNM/11.3).

WHO. (2013). *WHO database on child growth and malnutrition*. Geneva: World Health Organization (WHO).

Wieringa, F. T., Dahl, M., Chamnan, C., Poirot, E., Kuong, K., Sophonneary, P., et al. (2016) The high prevalence of anemia in Cambodian children and women cannot be satisfactorily explained by nutritional deficiencies or hemoglobin disorders. *Nutrients, 8*(6), E348. https://doi.org/10.3390/nu8060348.

Wieringa, F. T., Dijkhuizen, M. A., & West, C. E. (2004). Iron and zinc interactions. *The American Journal of Clinical Nutrition, 80*, 787–788.

Winichagoon, P. (2013). Thailand nutrition in transition: situation and challenges of maternal and child nutrition. *Asia Pacific Journal of Clinical Nutrition, 22*, 6–15.