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for dairy nutrition and health



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New insights on the nutrition and health  
status of Southeast Asian children



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# Assessing diets across multi-centers: Design, applications, and challenges

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The Seven Countries Study is one of the earliest multi-country studies conducted in the nutrition field. The cohorts in this study—from the USA, Finland, Yugoslavia, the Netherlands, Italy, Greece, and Japan—had contrasting lifestyles, eating habits, and risk factor levels for coronary heart disease (CHD). The study found that despite the variations in the cohorts, the major risk factors for CHD are the same, demonstrating the value of cross-country nutritional epidemiological research.<sup>1</sup>

## Value of cross-country nutritional epidemiological research

- Typically, there are greater variations between countries than within, and the variations are valuable for the measurement of prevalence and incidence of diseases, particularly when the disease is rare.
- The population context of individual characteristics has shown to be a stronger determinant of disease at the population level than individual-level risk factors.
- Aggregated data of cross-country research is particularly useful when measurements at the individual level are not available.
- Such studies provide the opportunity to demonstrate the robustness of certain findings when they can be reproduced in another country or geographical region.

## Multi-country research: Points to consider

Traditionally, nutritional parameters used for comparison were dietary or energy intake or biomarkers of nutrients (e.g., urinary markers of nitrogen and potassium).<sup>2</sup> However, in more recent years, dietary indices (assessment tools that quantify the quality of dietary intake) and data-driven dietary patterns have been adopted. Diet scores have also been used to examine diet quality.<sup>3,4</sup>

Study harmonization is another important consideration. Study harmonization ensures the comparability of dietary data collected across countries or centers and can be undertaken through two broad approaches: pre-study harmonization and post-hoc harmonization. A case in point is the NiPPeR Study, a multi-country, double-blind randomized trial that compared the effects of the study drink compared to a standard nutrition drink on the maintenance of healthy glucose levels in women at 28 weeks of gestation and the health of their offspring.<sup>5</sup> Pre-study harmonization of food-frequency questionnaires (FFQ) were done where food items were categorized into core or site-specific food groups.<sup>6</sup>

The similarity between pooled and site-specific analyses for 'healthy' and 'less healthy' dietary patterns suggests that key dietary information was retained in the pooled dietary patterns.

When conducting a nutrition study in heterogeneous populations:

- Having a diet/nutrition background and training is important
- Prior understanding of each other's cultural foods helps with discussion and harmonization
- Have flexibility (e.g., in the administration of FFQs, categorization of food under different food groups during administration, use of local food examples for broad food groups)
- Consider participant burden when filling out the FFQ

Table. Benefits and drawbacks of multi-country comparative research<sup>7</sup>

Benefits	Drawbacks
<ul style="list-style-type: none"><li>• Encourage a multi-level analysis that explores local, national, and global influences on diet</li><li>• Engender an appreciation of the need to situate analyses of health within the wider socio-political setting</li><li>• Help researchers see familiar issues from new perspectives and thereby encourage innovative solutions</li><li>• Encourage researchers to engage in both ideological and methodological critical reflexivity</li><li>• Encourage conceptual and methodological development through the exchange of ideas and experience between diverse research teams</li></ul>	<ul style="list-style-type: none"><li>• Increase logistical complexity and costs</li><li>• Analyses are superficial, being restricted to independent country descriptions rather than generating integrated insights</li><li>• Difficulties in balancing the need for meaningful findings at country levels and generating more holistic or global insights</li></ul>

## Key takeaways

- Carefully consider the reason for adopting a multi-country comparative design, the type of comparative analysis intended, and what can and cannot be learnt from the proposed research.
- Undertake multi-country comparative work that offers significant additional analytical purchase, and not merely because of funding imperatives; clearly articulate the analytical opportunities that would not be achieved through a single country design.
- Clearly articulate the relationship between the researchers and the commissioners and other stakeholders in the research and how this may shape, and perhaps compromise, the research process.

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# How national health surveys have an influence on national policies

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Health surveys are important for policy-making as they help understand:

- The magnitude of nutrition and health problems,
- The determinants of the problems, and
- The social and economic context of the nutrition and health problems.

Information obtained from these surveys can be used to develop policies that can be translated into effective programs or interventions. Survey information from other countries facilitates program or policy progress tracking and allows for comparison with other countries, which in turn, can lead to regional or global policy recommendations.

## National nutritional survey in Indonesia

The Indonesian government has been concerned about the problem of malnutrition in Indonesia. Thus, together with the reduction of maternal and infant mortality risk, the government has put the reduction of stunting as one of the three national priorities. As a result, the Indonesia Nutritional Status Study (SSGI) was launched in 2019 and is conducted every 1-2 years.

Table 1: Status of malnutrition from 2018 to 2021 in children <5<sup>1,2</sup>

	2018	2019	2021
Stunted	30.8%	27.7%	24.4%
Underweight	17.7%	16.3%	17%
Wasted	10.2%	7.4%	7.1%
Obesity	8%	-	3.8%

Results from the SSGI, in combination with the RISKESDAS studies (Basic Health Research by Ministry of Health (MOH), Indonesia), have shown that the national rate of stunting has been going down from 2018 to 2021 (Table 1).<sup>1,2</sup> The SSGI 2021 results also showed that the prevalence of stunting ranged from 10.9% in Bali to 37.8% in East Nusa Tenggara.<sup>2</sup> Additionally, 20 out of 34 provinces had a prevalence of stunting higher than the national prevalence. Based on these results, provinces with stunting and wasting of 'low,' 'chronic', 'acute', and 'chronic-acute public health problem' were determined.<sup>2</sup>

The results of SSGI 2021 were used to strengthen the Health Transformation Plan. The MOH determined six areas of focus: primary healthcare, referral health, health resilience system, health financing system, health human resources, and health technology transformation. Special attention was placed on the transformation of primary healthcare which was further broken into community education, primary prevention, secondary prevention, and improvement of capacity and capability of primary healthcare.<sup>3</sup>

In addition to health transformation, the SSGI 2021 resulted in a Presidential decree/regulation requiring<sup>4</sup>:

- the MOH to publish stunting prevalence annually,
- the assessment of stunting status at the district/city level to determine the local incentive fund from central government to districts/cities,
- the use of SSGI findings as the basis for evaluation and assessment of the progress of specific and sensitive interventions from all related sectors at the central and local levels.

Challenges that arise from running such a large health survey include the need for good governance structure and function when various surveys are available, pursuing quality data, obtaining data for national and sub-national levels at the same time, and uncertainties caused by the pandemic.

References: 1. Ministry of Health, Republic of Indonesia. Hasil Utama RISKEDAS 2018. 2. Ministry of Health, Republic of Indonesia. Buku Saku: Hasil Studi Status Gizi Indonesia (SSGI) Tingkat Nasional, Provinsi, dan Kabupaten/ Kota Tahun 2021. 3. Ministry of Health, Republic of Indonesia. Kementerian Kesehatan RI Bertransformasi. Available at: <https://kesmas.kemkes.go.id/konten/133/0/kementerian-kesehatan-ri-bertransformasi>. Accessed June 2022. 4. PERPRES Order No. 72. Peraturan Presiden (PERPRES) tentang Percepatan Penurunan Stunting. 5 August 2021. LN.2021/No.172, jdih.setneg.go.id: 23 hlm. Available at: <https://peraturan.bpk.go.id/Home/Details/174964/perpres-no-72-tahun-2021>. Accessed June 2022.

# SEANUTS II: The what, why, and how

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Nutrition is a human right, yet malnutrition among young children worldwide remains a critical issue and a complicated challenge to resolve. In 2021, UNICEF estimated 144 million children under 5 years were affected by stunting; 47 million by wasting; and 38 million by overweight.<sup>1</sup> The recent global pandemic has only compounded this call to action.

Global challenges require global collaborations to solve them. In line with FrieslandCampina's commitment to supporting the UN Sustainable Development Goals (SDGs), the company strives to work with stakeholders to deliver affordable products and raise awareness on better nutrition worldwide. The second South East Asian Nutrition Surveys (SEANUTS II), reviewed herewith, would not have been possible without collaboration with respected regional scientific leaders and many other partners.

## Study design

SEANUTS II aimed to provide an in-depth understanding of dietary intake, nutritional status, malnutrition prevalence, and lifestyle behavior among Southeast Asian children. As a follow-up to SEANUTS I conducted in 2010, this study collected similar data while assessing additional variables (Table 1). Key new variables included are metabolomic phenotyping, quality of protein intake, physical endurance and strength, and food insecurity. Protocol amendments were also made in light of the pandemic that included COVID-19-related entries into the questionnaires to assess the impact of the pandemic on lifestyle behavior changes.

Data collection for SEANUTS II started in 2019, but rapidly encountered unforeseen complications during the COVID-19 pandemic. However, with utmost priority given to the safety of participants and field staff, data collection was successfully concluded in 2021, and the study moved into its data validation and management phase. The first results are hereby shared during this conference dated June 17<sup>th</sup>–18<sup>th</sup> 2022 and will be in upcoming publications.

The study's subjects were children aged 0.5–12 years from four Southeast Asian countries: Indonesia, Malaysia, Thailand, and Vietnam. Due to restrictions and safety concerns, the study team was compelled to reduce sample sizes (N) and study sites (n) in Indonesia and Malaysia (Indonesia, N=7,595 to 3,465; n=46 to 21; Malaysia, N=3,864 to 2,989; n=12 to 8). However, a largely representative amount of data was still collected from Thailand (N=3,545 to 3,478; n=11) and Vietnam (N=3,904 to 4,001; n=12), where data collection proceeded as per the original scope.

As of the present time, despite challenges from the pandemic, the SEANUTS II team has managed to generate a comprehensive dataset of more than 15 million data points. This includes 1.5 million data points on anthropometry, 1.8 million on nutrient intake, and 2.2 million on child nutritional habits. These results reflect the monumental effort undertaken by all participants.

## Next steps

Data must be translated into action to be meaningful. Moving forward, FrieslandCampina intends to deploy the results of SEANUTS II through several channels. These include engagements with regional professionals in health, nutrition, and medicine; scientific publications and presentations; provision of input for country-specific policies; input for public education on healthy eating and living; and insights for product development.

The company welcomes open discussions on ideas for future directions, as FrieslandCampina is committed to ensuring SEANUTS II's results benefit children not only in the countries assessed, but throughout the region.

**Table 1.** Overview of data parameters collected during SEANUTS II

Domains of interest	Variables/ Assessments
Nutritional status	Z-scores: Height for Age, Weight for Age Weight for Height, BMI for Age
Prevalance of malnutrition	% of stunting, underweight, wasting, overweight, obesity
Biochemical status	<b>Metabolomic phenotyping*</b> % of anemia, iron deficiency (including inflammation markers), vitamin A, B <sub>12</sub> *, D deficiencies, <b>zinc deficiency*</b>
Dietary intake (24-hour recall + questionnaires)	% of meeting international and local RDA, <b>dairy consumption, protein quality*</b> , dietary habits
Physical activity (questionnaires, <b>accelerometers*, fitness test*</b> )	Time spent on physical activity/ screen time, <b>endurance*, strength*</b>
Sun exposure	Time spent in the sun, <b>exposure to UVB*</b>
Socio-demographics and others	Social economic status, <b>food (in)security*</b> , environmental factors, <b>body image*</b>

\*=additional compared to SEANUTS I

**References:** 1. UNICEF / WHO / World Bank Group. Joint child malnutrition estimates: Key findings of the 2021 edition. Available at: <https://www.who.int/publications/i/item/9789240025257>. Accessed June 2022.



# Malnutrition: What are we looking at? Single, double, or triple burden of malnutrition?

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The World Health Organization (WHO) defines malnutrition as deficiencies or excesses in nutrient intake, imbalance of essential nutrients, or impaired nutrient utilization.<sup>1</sup> Single malnutrition occurs when only one form of malnutrition occurs. The double burden of malnutrition is defined by the coexistence of overnutrition (overweight and obesity), along with undernutrition (stunting and wasting) within individuals, households, and populations. The triple burden of malnutrition refers to the coexistence of overnutrition, undernutrition, and micronutrient deficiencies (Figure 1).<sup>2</sup>

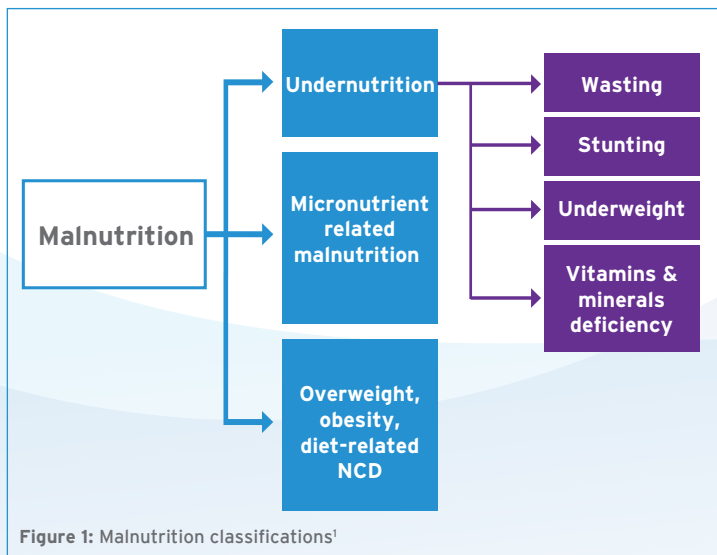


Figure 1: Malnutrition classifications<sup>1</sup>

The WHO reported that in 2020, for children under 5 years, 38.9 million were affected by overweight, 149.2 million were affected by stunting, and 45.4 million were affected by wasting.<sup>3</sup> Most countries in Southeast Asia have a high prevalence of malnutrition among children under 5 years.<sup>3,4</sup> In 2020, more than half of all children affected by wasting live in southern Asia and Asia is home to more than 75% of all children suffering from severe wasting.<sup>3</sup>

Globally, the number of stunting in children under 5 years has been improving from 2000 to 2020. There has been a decrease in the number of children affected with stunting in lower-middle and upper-middle-income countries. However, the number of children affected with overweight has remained unchanged for the past two decades.<sup>3</sup>

Nutrition is a key factor. Dietary diversity is required to:

- Ensure children receive all the nutrients they need
- Reduce the risk of undernutrition, including micronutrient deficiency
- Establish good eating habits that can persist into later years

## The importance of essential amino acids

Amino acids (AAs) are crucial to ensure the proper function of the body. Of the hundreds of AAs found in nature, only 20 are required to make all the proteins in the human body. Of this number, nine are essential (EAAs) which the body cannot synthesize and must be acquired through external sources of protein.<sup>5</sup> Protein quality is the measure of the quantity of EAAs and digestibility of protein sources, and represents the nutritional capacity to meet the requirements of the body.<sup>6</sup>

When an EAA is not provided adequately, utilization of other EAAs is limited to the rate at which the limiting EAA is available (Figure 2).<sup>7,8</sup> A diet consisting of low-quality proteins can lead to reduced growth.<sup>9</sup> High-quality proteins, such as milk, are important to support the growth of children.<sup>9</sup>

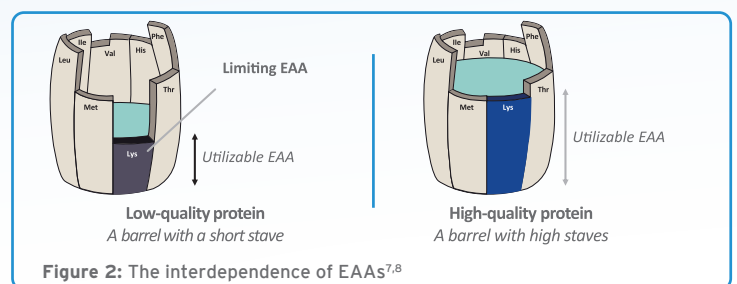


Figure 2: The interdependence of EAAs<sup>7,8</sup>

**References:** 1. World Health Organization. Malnutrition. 2021. Available at: <https://who.int/news-room/fact-sheets/detail/malnutrition>. Accessed June 2022. 2. Sunuwar DR, Singh DR, Pradhan PMS. Prevalence and factors associated with double and triple burden of malnutrition among mothers and children in Nepal: Evidence from 2016 Nepal demographic and health survey. *BMC Public Health* 2020;20(1):405. 3. United Nations Children's Fund (UNICEF), World Health Organization, International Bank for Reconstruction and Development/ The World Bank. Levels and trends in child malnutrition: Key findings of the 2021 edition of the joint child malnutrition estimates. Geneva: World Health Organization; 2021. 4. Food and Agriculture Organization of the United Nations. Asia and the Pacific Regional Overview of Food Security and Nutrition 2018 - Accelerating progress towards the SDGs. Bangkok. 2018. 5. Lopez MJ and Mohiuddin SS. Biochemistry, Essential Amino Acids. [Updated 2022 Mar 18]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2022 Jan-. Available at: <https://www.ncbi.nlm.nih.gov/books/NBK557845/>. Accessed June 2022. 6. Gwin JA, et al. Physiological limitations of protein foods ounce equivalents and the underappreciated role of essential amino acid density in healthy dietary patterns. *J Nutr* 2021;151(11):3276-3283. 7. Elango R, Ball RO, Pencharz PB. Indicator amino acid oxidation: Concept and application. *J Nutr* 2008;138(2):243-246. 8. Dupont C. Protein requirements during the first year of life. *Am J Clin Nutr* 2003;77(6):1544S-1549S. 9. Uauy R, et al. Role of protein and amino acids in infant and young child nutrition: Protein and amino acid needs and relationship with child growth. *J Nutr Sci Vitaminol (Tokyo)* 2015;61 Suppl:S192-194.



# Nutritional status of children in Southeast Asia: The SEANUTS II study

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Childhood malnutrition in various forms remains an issue of concern across Southeast Asia.<sup>1</sup> In Indonesia alone, UNICEF estimates two million children suffer from severe acute malnutrition, while 15% of adolescents are overweight or obese.<sup>2</sup> Up-to-date information is needed to develop and implement programs and policies to effectively address these health issues.

SEANUTS II evaluated the nutritional status and prevalence of different forms of malnutrition in Southeast Asian children by assessing anthropometric data (height, weight, and BMI) and calculating Z-scores. These were then compared to classification criteria for types of malnutrition including stunting, wasting, underweight, thinness, overweight, and obesity.

Anthropometry was analyzed in four subgroups by age (0.5–0.9, 1–3.9, 4–6.9, and 7–12.9 years), with a fifth separate subgroup (<5 years) focusing on younger children. Total sample sizes by country ranged from 2,475 (Indonesia) to 4,001 (Vietnam). Notably, Indonesia and Malaysia data were collected entirely pre-pandemic; Vietnam data was collected entirely mid-pandemic; while Thailand data was collected both pre- and mid-pandemic.

## Key findings

**Stunting affects 1-in-4 Indonesian children.** Of the four SEANUTS II countries, Indonesia had the highest prevalence of stunting among children between 0.5–12.9 years (24.6%). In comparison, the second highest prevalence was less than half the proportion (Malaysia: 8.9%). Stunting in Indonesia was also significant among children <5 years (28.4%) and disproportionately affected rural over urban areas.

In Malaysia, Thailand, and Vietnam, stunting was found in <10% of children assessed, with the lowest prevalence in Thailand (4.6%). A rural-urban divide was also observed in Vietnam but not in the other two countries.

**Overweight and obesity rates rise with age.** In all four countries, there were significant increases in overweight and obesity with increasing age (Figure 1). While less than 5% among children aged <1 year were overweight or obese, the prevalence rose to 17–33% among those aged 7–12.9 years. In Malaysia, sharp increases in the prevalence of both occurred in the 4–6.9 years and the 7–12.9 years age groups.

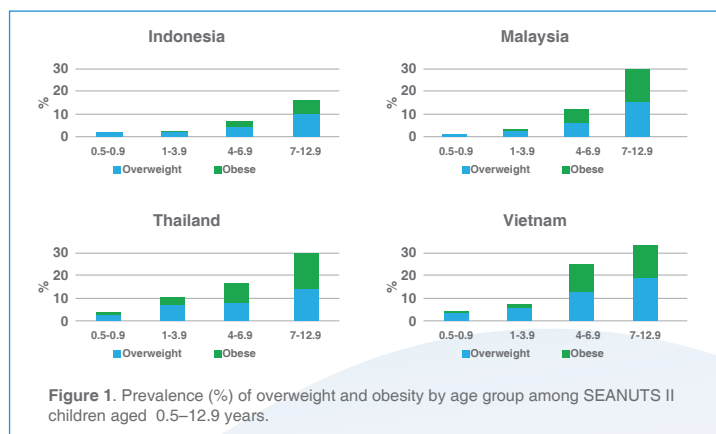


Figure 1. Prevalence (%) of overweight and obesity by age group among SEANUTS II children aged 0.5–12.9 years.

In Malaysia, Thailand, and Vietnam, obesity appeared to affect boys <13 years disproportionately over girls (Malaysia: 10.6% vs 6.8%; Thailand: 13.3% vs 10.1%; Vietnam: 14.3% vs 6.8%). In general, obesity was more prominent in all children <13 years in urban over rural areas, except Malaysia (urban: 8.2%, rural: 10.3%).

## Future directions

The Indonesian government declared stunting a priority issue in its 2020–2024 National Medium-Term Development Plan (RPJMN) and aims to lower the national prevalence of stunting to 14% by 2024. To achieve this, a strategic action plan was rolled out to accelerate stunting reduction through a series of specific and sensitive interventions including nutrient supplementation, breastfeeding promotion and counseling, and food fortification and assistance.<sup>3</sup>

Upcoming in-depth analyses of nutritional status in SEANUTS II will examine its links with parameters such as household income, parental education, environmental factors, food insecurity, dietary intake, and blood biochemistry. The outcomes of such studies are hoped to provide added input for nutrition policy, education programs, and other interventions in the region.

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# The impact of breakfast and dairy on a child's health

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Breakfast is an important meal taken after a long period of overnight fasting and taken before 10 am. The United States Department of Agriculture (USDA) recommends that breakfast contains portions from different food groups, i.e., milk, fruits or vegetables, and cereals.<sup>1</sup>

## Breakfast and health

A good breakfast provides energy and is associated with the following benefits: slow release of glucose in the bloodstream for low glycemic index cereal-based breakfasts,<sup>1</sup> positive effects on cognitive performance including attention and memory in children,<sup>1,2</sup> improved school performance,<sup>2</sup> and reduced risk of obesity and improvement in mental abilities.<sup>1</sup>

Milk and dairy consumption contributes to meet the nutritional recommendations and is associated with reducing the risks associated with chronic diseases<sup>3,4</sup>:

- Reduces the risk of childhood obesity<sup>3</sup>
- Improves body composition and facilitates weight loss<sup>3</sup>
- Reduces risk of diabetes mellitus and cardiovascular diseases<sup>3</sup>
- Increases bone mineral density<sup>3,4</sup>

**Table.** Effect of breakfast consumption on children and adolescents<sup>5</sup>

<b>Morbidity risk factors</b>	<ul style="list-style-type: none"> <li>• Lower risk of insulin resistance</li> <li>• Lower risk of other risk factors for metabolic syndrome</li> <li>• Higher cardiorespiratory fitness</li> <li>• Lower total adiposity</li> </ul>
<b>Cognitive performance</b>	<ul style="list-style-type: none"> <li>• Increases attention</li> <li>• Improved response time (short-term memory test)</li> <li>• Lower response variability</li> <li>• Positive selective attention and visual scanning speed</li> </ul>
<b>Quality of life</b>	<ul style="list-style-type: none"> <li>• Breakfast is a significant predictor of self-rated health measure</li> <li>• Skipping breakfast is associated with stress, anxiety, and depression</li> <li>• Linked to increased well-being</li> </ul>
<b>Academic achievement</b>	<ul style="list-style-type: none"> <li>• Higher cognitive performance: mathematics sentence-reading test</li> <li>• Significantly associated with domain writing</li> </ul>

Skipping breakfast, on the other hand, is associated with an increase in the waist-to-height ratio, weight and body mass index (BMI), in addition to abdominal obesity.<sup>6</sup> Children who skip breakfast are also likely to have increased appetite and large portions during their subsequent meals.<sup>7</sup> Consequently, they may have a higher total energy intake and at increased risk to be overweight or obese.<sup>7</sup>

## Breakfast surveys in southeast Asian countries

In Bangkok, Thailand, the earlier parents woke up, the higher the likelihood of children (6-12 years of age) having breakfast. However, the frequency of breakfast decreased as the children grew up.<sup>8</sup>

In Malaysia, the prevalence of breakfast skipping was 11.7% among children aged 6-12 years. Skipping breakfast in these children was associated with a higher BMI-for-age Z-score and a greater likelihood of being overweight and obese.<sup>9</sup>

The 2012 SEANUTS I study in Indonesia found that among children aged 2 to 12.9 years, 31.6% of children had adequate breakfast consumption ( $\geq 25\%$  of RDA) and 21.6% of children had a good breakfast (contains a source of energy, protein, and vitamins/minerals). Only 9.2% of children received both an adequate and a good-quality breakfast.<sup>10</sup>

The rate of breakfast skipping in Vietnam among urban elementary school students was 9.4% with an average of 2.8 days of skipped breakfast each week. The main foods for breakfast in Vietnam were reported to be Vietnamese noodles, rice, sticky rice, bread, and rice porridge. The ratio of animal:plant protein at breakfast was 61.5%.<sup>11</sup>

The main breakfast food to provide energy to children in Southeast Asia is rice, followed by other foods such as noodles and bread. The habit of regular breakfast consumption can support health and provides energy for the whole morning while providing a positive impact on cognitive performance and quality of life.<sup>5</sup>

**References:** 1. Rani R, Dharaiya CN, Singh B. Importance of not skipping breakfast: A review. *Int J Food Sci Tech* 2021;56(1):28-38. 2. Adolphus K, Lawton CL, Dye L. The effects of breakfast on behavior and academic performance in children and adolescents. *Front Hum Neurosci* 2013;7:425. 3. Thorning TK, Raben A, Tholstrup T, et al. Milk and dairy products: Good or bad for human health? An assessment of the totality of scientific evidence. *Food Nutr Res* 2016;60:10.3402/fnr.v60.32527. 4. Sipple LR, Barbano DM, Drake M. Invited review: Maintaining and growing fluid milk consumption by children in school lunch programs in the United States. *J Dairy Sci* 2020;103(9):7639-7654. 5. Lundqvist M, Vogel NE, Levin LA. Effects of eating breakfast on children and adolescents: A systematic review of potentially relevant outcomes in economic evaluations. *Food Nutr Res* 2019;63:10.29219/fnr.v63.1618. 6. Ricotti R, Caputo M, Monzani A, et al. Breakfast skipping, weight, cardiometabolic risk, and nutrition quality in children and adolescents: A systematic review of randomized controlled and intervention longitudinal trials. *Nutrients* 2021;13(10):3331. 7. Nuru H and Mamang F. Impact of breakfast skipping toward children health: A review. *Int J Community Med Public Health* 2015;2(3):201-209. 8. Sirichakwal PP, Janesiripanich N, Kunapun P, et al. Breakfast consumption behaviours of elementary school children in Bangkok metropolitan region. *Southeast Asian J Trop Med Public Health* 2015;46(5):939-948. 9. ee ES, Nurliyana AR, Norimah AK, et al. Breakfast consumption among Malaysian primary and secondary school children and relationship with body weight status - Findings from the MyBreakfast Study. *Asia Pac J Clin Nutr* 2018;27(2):421-432. 10. Haharap H, Widodo Y, Sandjaja S, et al. Quantity and quality of breakfast in children aged 2.0 to 12.9 years in Indonesia. *Gizi Indo* 2019;42(1):31-42. 11. Tran KV, et al. Survey of nutrition situation, dietary intake, breakfast, and physical activities of children in Hanoi and Ho Chi Minh City. 2018.

# Dietary habits of children in the Southeast Asian region: Findings from SEANUTS II

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Starting with healthy dietary practices early in life is key to healthy growth, normal cognitive development, and longer-term risk reduction of non-communicable diseases (NCDs).<sup>1</sup>

Within SEANUTS II, investigators assessed current dietary habits among children of four Southeast Asian countries—Indonesia, Malaysia, Thailand, and Vietnam—based on two lines of inquiry.

These were:

- Infant and young child feeding (IYCF) practices among children aged 6–23 months (n=3,090) using IYCF indicators as defined by WHO-UNICEF;<sup>2</sup> and
- Food habits among children aged 2–12.9 years (n=10,811), covering types of food consumed, meal intake patterns, and dietary quality.

For both groups, data was collected through questionnaires completed in person by mothers and caretakers (for children <10 years) and by older children ≥ 10 years, facilitated by trained interviewers.

## Infants and young children: Feeding practices

**Breastfeeding.** Over 95% of all young children were ever breastfed; in Indonesia and Malaysia, over 65% received early initiation of breastfeeding (within 1 hour of birth) versus <46% in Thailand and Vietnam. Next to this, <50% of all children aged 12–23 months were still breastfed.

**Complementary feeding.** Many participants did not consume a WHO-UNICEF minimal acceptable diet (MAD),<sup>2</sup> though this varied widely between countries (e.g., Malaysia: 32.2%; Vietnam: 80.1%).

## Children aged 2 to 12.9 years: Food habits

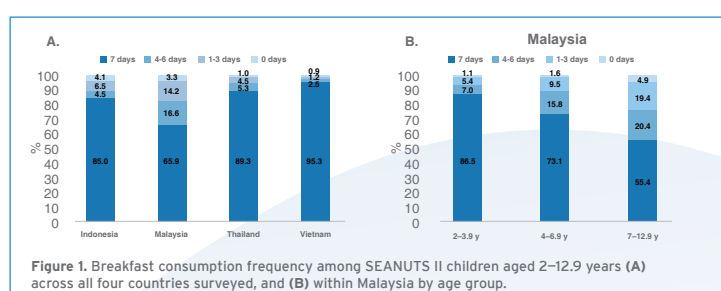
**Types of food.** Overall, less than 50% of children consumed one daily serving of fruits or vegetables. Eggs were consumed more regularly in Thailand and Indonesia (>55% of children took ≥4 eggs per week) than Malaysia (33%) and Vietnam (14%).

Looking at dairy consumption, 60.1% (Vietnam) to 88.1% (Thailand) of children took more than four servings (≥ 100 ml) of dairy a week.\* However, with the exception of Malaysia, most children did not consume dairy during breakfast.

\* One serving of dairy in SEANUTS II is defined as minimally 15 g powdered milk, 100 ml liquid milk, 50 g yogurt, 5 g cheese, 10 g ice cream, or 10 g condensed milk.

**References:** 1. World Health Organization. Fact sheets: Healthy diet. Available at: <https://www.who.int/news-room/fact-sheets/detail/healthy-diet>. Accessed June 2022. 2. World Health Organization. Indicators for assessing infant and young child feeding practices: definitions and measurement methods. Available at: <https://www.who.int/publications/i/item/9789240018389>. Accessed June 2022.

**Breakfast consumption.** While almost all children surveyed in Thailand, Indonesia, and Vietnam consumed a daily breakfast, one in three (34.1%) in Malaysia did not (**Figure 1A**). Notably, daily breakfast consumption by Malaysian children trended further down with increasing age, with only half of children aged 7–12 years eating breakfast daily (**Figure 1B**).



**Diet quality.** A deeper look at Thai primary school children (aged 7–12.9 years) found that those consuming sufficient calorie breakfasts had lower proportions of inadequate macro- and micronutrient intake (i.e., energy, protein, iron, zinc, vitamins A, C, D, B<sub>1</sub>, B<sub>2</sub>, B<sub>3</sub>, and B<sub>12</sub>).

Conversely, those with lower-calorie breakfasts were more likely to have inadequate total daily nutrient intake. This may indicate a relationship between calorie intake at breakfast and daily diet quality among primary school children.

## Further investigations

There remains room to improve IYCF practices and child dietary habits in the four SEANUTS II countries through nutrition education that supports their growth, health, and behavioral development.

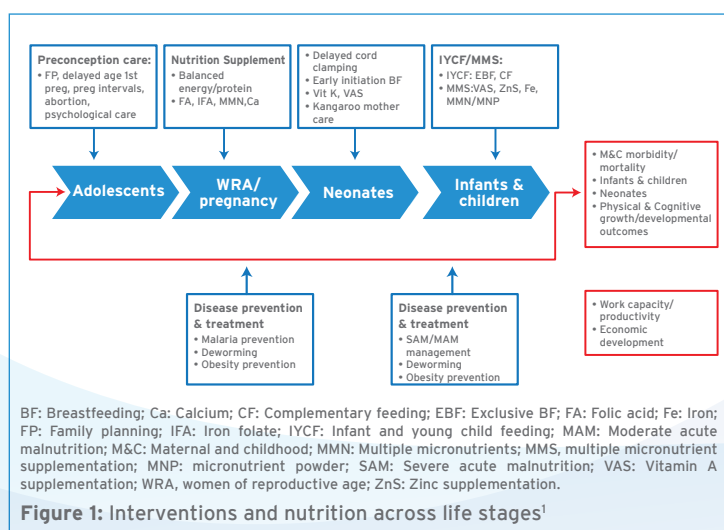
Moving forward, SEANUTS II investigators aim to comprehensively analyze the nutritional quality of breakfasts and other meals consumed by study participants via parameters such as dietary diversity and the healthy eating index; and to further examine the relationship between nutritional status and dietary quality.



# Micronutrients in children: The foundation that matters

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Nutrition over the life stages is an inter-generational cycle. Adequate nutrition and micronutrient consumption during pregnancy lay the foundation for the development of neonates, infants, and children that grow into adolescence and further adulthood. Nutritional intervention across all life stages involves either single or multiple micronutrients (MMN). These MMNs work together with other macronutrients to affect various maternal and child outcomes (Figure 1).<sup>1</sup>



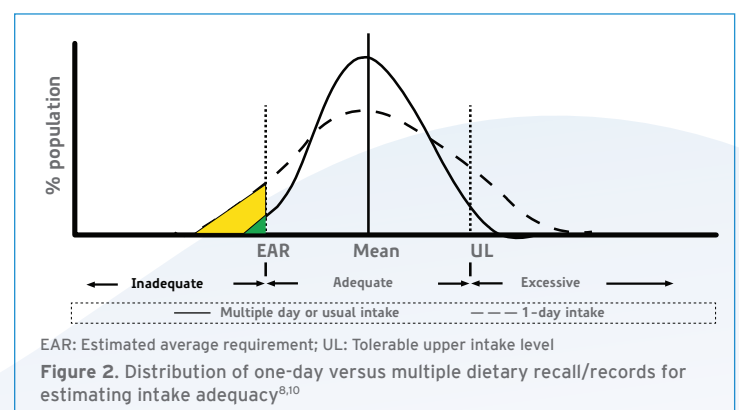
Many of the undernourished population live in poverty and have a high burden of micronutrient (MN) deficiencies.<sup>2</sup> Globally, each year, maternal and child MN deficiencies account for 0.5 million or more deaths of those under 5.<sup>3</sup> MMN deficiencies, especially iron and iodine, are associated with impaired children's cognitive development and compromised adult cognitive function.<sup>4</sup> In addition, MN deficiency especially iron, can be present in overweight or obese children despite adequate intake due to underlying inflammation that affects nutrient absorption and utilization.<sup>5,6</sup>

## Assessing MN status

In nutritional assessments, dietary intake and biomarkers are measured to correlate with functional and clinical outcomes. Dietary intake assesses nutrient exposure whereas biomarkers assess the nutrition status and are linked closely to health outcomes.<sup>7</sup>

**References:** 1. Bhutta ZA, Das JK, Rizvi A, et al. Evidence-based interventions for improvement of maternal and child nutrition: what can be done and at what cost? *Lancet* 2013;382(9890):452-477. 2. Bailey RL, West KP Jr, Black RE. The epidemiology of global micronutrient deficiencies. *Ann Nutr Metab* 2015;66 Suppl 2:22-33. 3. Brown KH, Engle-Stone R, Kagin J, et al. Use of optimization modelling for selecting national micronutrient intervention strategies: An example based on potential programs for control of vitamin A deficiency in Cameroon. *Food Nutr Bull* 2015;36(3 Suppl):S141-S148. 4. Jáuregui-Lobera. Iron deficiency and cognitive functions. *Neuropsychiatr Dis Treat* 2014;10:2087-2095. 5. Aeberli I, Hurrell RF, Zimmermann MB. Overweight children have higher circulating hepcidin concentrations and lower iron status but have dietary iron intakes and bioavailability comparable with normal-weight children. *Int J Obes (Lond)* 2009;33(10):1111-1117. 6. Zimmermann MB, Zeder C, Muthayya S, et al. Adiposity in women and children from transition countries predicts decreased iron absorption, iron deficiency, and a reduced response to iron fortification. *Int J Obes (Lond)* 2008;32(7):1098-1104. 7. ussell R, Chung M, Bulk EM, et al. Issues and Challenges in Conducting Systematic Reviews to Support Development of Nutrient Reference Values: Workshop Summary. AHRG Publication No. 09-0026-2. Rockville, MD: Agency for Healthcare Research and Quality, March 2009. 8. Gibson RS. Chapter 8b: Evaluation of intakes and diets. In: Principles of Nutritional Assessment. 3rd Ed. March 2022. Available at: <https://nutritionalassessment.org>. Accessed June 2022. 9. Carriquiry AL. Assessing the prevalence of nutrient inadequacy. *Public Health Nutr* 1999;2(1):23-33. 10. Institute of Medicine. Dietary Reference Intakes for Thiamin, Riboflavin, Niacin, Vitamin B6, Folate, Vitamin B12, Pantothenic Acid, Biotin, and Choline. 1998. Washington, DC: The National Academies Press. 11. Brown KH, Moore SE, Hess SY, et al. Increasing the availability and utilization of reliable data on population micronutrient (MN) status globally: The MN Data Generation Initiative. *Am J Clin Nutr* 2021;114(3):862-870.

In determining the prevalence of the population's nutrient inadequacy, the Estimated Average Requirement (EAR) should be used as the cut-off (Figure 2).<sup>8-10</sup> Furthermore, dietary assessment using one-day recall or records does not account for intra-variability of the habitual intake.<sup>8</sup> Hence, using either the 24-hour recall data or recommended dietary allowance (RDA) value as a cut-off will result in an overestimation of the prevalence of inadequate intake.<sup>8,10</sup>



Biomarker data on MN status globally is scarce, especially for preschool children and non-pregnant women.<sup>11</sup> Updated and good-quality data on population MN status, particularly in low- and middle-income countries, is needed to<sup>11</sup>:

- Guide public health interventions if the magnitude requires, rather than case-by-case treatment
- Identify the most-affected subpopulations or areas for targeted intervention
- Determine whether the program's main objectives have been met
- Use the data to explore the possibility of toxicity risk in the situation of excessive intake
- Examine the relationships between MN status and various health outcomes



# Nutrient intakes and micronutrient deficiencies of children in Southeast Asia: Results from SEANUTS II

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Macro- and micronutrient deficiencies among children remain challenges to Southeast Asian countries despite community-based nutritional programs. Poor nutrition in children has long-term effects not just on individual health but on communities.<sup>1</sup>

Within SEANUTS II, an assessment of dietary intakes and nutritional-biochemical status of children aged 0.5–12.9 years was carried out in Indonesia, Malaysia, Thailand, and Vietnam.

Dietary intake data was collected through one-day 24-hour food recall interviews. Local food composition tables were used to calculate nutrient intakes and then compared to local Estimated Average Requirement (EAR) data.\* For nutrients with no EAR information, Recommended Dietary Allowance (RDA) was used instead.†

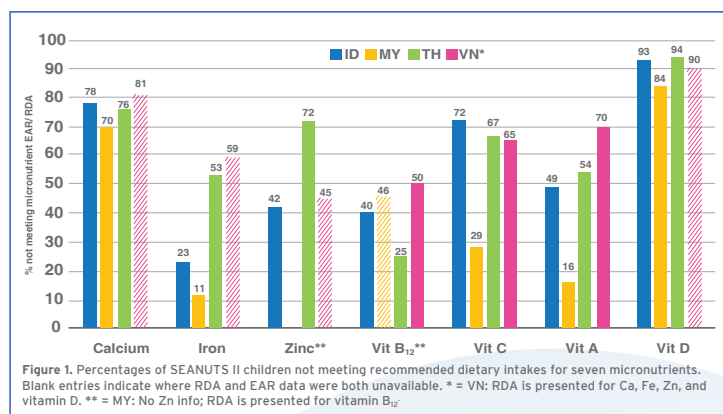
Biochemistry data was collected from finger prick or venepuncture blood samples. The public health significance of nutrient deficiency prevalence was assessed based on World Health Organization (WHO) cut-off values.<sup>2</sup> Notably, blood data could not be extrapolated in Indonesia due to the small sample size.

## Key findings: Nutrient intake

**Protein sufficiency.** Protein intake was not a significant issue in all countries except in Indonesia, where 66% of Indonesian children aged 7–12.9 years were not meeting the RDA for protein. Future analyses will focus on understanding the quality of protein intake.

**Varied micronutrient shortfalls.** As a whole, each country had different inadequacies in the seven micronutrients assessed (Figure 1). However, all four countries had low calcium and vitamin D intake in common; >70% of all children in each country did not meet the average needs for calcium, and >84% of all children in each country did not meet the average needs for vitamin D. Low calcium intake was more common in older children (>4 years) whereas vitamin D intake was low across all age groups.

The investigators also noticed the following: low iron intake among children 0.5–0.9 years in Indonesia, Thailand, and Vietnam; declining intakes of zinc, vitamin A, and vitamin C with increasing age groups; and poor vitamin B<sub>12</sub> intake in the youngest (0.5–0.9 years) and oldest (7–12.9 years) age groups, except for Vietnam, where mainly the oldest children were impacted.



## Key findings: Nutritional biochemistry

**Anemia among young children.** While overall anemia prevalence in the four countries was of mild public health significance (12–19.5%), subgroup analysis showed moderate-to-severe prevalence among children 0.5–0.9 years (38.6–61.8%), and mild-to-moderate prevalence among children 1–3.9 years (15–36.9%).<sup>2</sup> In Vietnam, higher anemia prevalence in children <5 years was linked with household incomes at the bottom 40%.

**Vitamin D insufficiency in older children.** Vitamin D insufficiency was seen in an estimated one-in-four children in Indonesia and Malaysia, and one-in-three in Vietnam. By age group, vitamin D insufficiency primarily affected older children (7–12.9 years; prevalence 33.2–41.7%) in the three countries. In Vietnam, vitamin D insufficiency was also more prevalent in children whose household income belongs in the top 20%.

## Strategic actions

Action plans to improve dietary intake quality in the SEANUTS II countries are advised to include strong nutritional education and counseling in schools and communities, as well as quality school meal programs. Periodic nutritional surveys are also recommended to assess the efficacy of future approaches to reduce the prevalence of anemia and micronutrient deficiencies of concern.

\* EAR: average daily level of nutrient intake sufficient to meet the requirements of 50% of healthy people in a particular life stage and gender group.<sup>3</sup>

† RDA: average daily level of nutrient intake sufficient to meet the requirements of 97–98% of all healthy people.<sup>3</sup>

**References:** 1. World Health Organization (2021). Fact sheets: malnutrition. Available at: <https://www.who.int/news-room/fact-sheets/detail/malnutrition>. Accessed June 2022. 2. World Health Organization (2006). Guidelines on food fortification with micronutrients. Available at: <https://www.who.int/publications/i/item/9241594012>. Accessed June 2022. 3. Institute of Medicine (US) Food and Nutrition Board (1998). Dietary reference intakes: A risk assessment model for establishing upper intake levels for nutrients. Washington (DC): National Academies Press (US); 1998. Available at: <https://www.ncbi.nlm.nih.gov/books/NBK45182/>. Accessed June 2022.



# Does COVID-19 have an impact on the growth, health, and nutrition of children?

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Since the start of the COVID-19 pandemic, approximately 20 million people in the ASEAN region have been infected.<sup>1</sup> The pandemic increased the unemployment rate,<sup>2</sup> adversely affected household income, and as such, more than half of the households in the ASEAN region experienced financial difficulty.<sup>3</sup>

## COVID-19: Impact on children's growth, health, and nutrition status

The lockdown caused an increase in eating of snacks, screen time, and sleep difficulty among children aged 3–5 years.<sup>4</sup> E-learning also poses a neurological risk for the developing brain. Screen exposure leads to structural changes in the brain and may yield adverse effects on the visual system.<sup>5</sup>

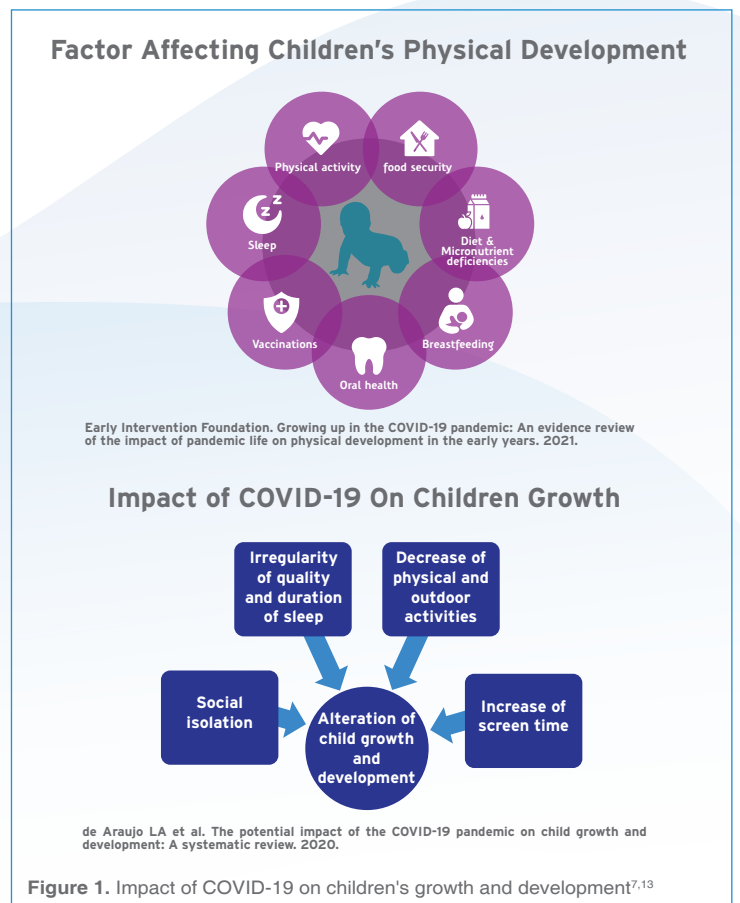
In 2020, 47 million children under 5 years suffered from wasting.<sup>6</sup> The pandemic caused a decline in household food security<sup>7</sup> which, in the early years, is associated with poor early childhood development; negative impacts on child cognitive, language, and motor skills; and alteration in socioemotional and behavioral development.<sup>7</sup> Food insecurity is also associated with malnutrition and stunting.<sup>8</sup>

The pandemic has led to an increase in the prevalence of perinatal psychiatric symptoms, such as anxiety, depression, and post-traumatic stress disorder.<sup>9</sup> This can affect the developing fetus and negatively impact the child's behavior and psychopathology.<sup>10</sup>

## Possible longer-term impact of COVID-19

Other aspects affected by the pandemic include immunization, mental health, and trauma. In 2020, UNICEF reported that 23 million children missed basic childhood vaccines. The impact of that was a 79% increase in measles cases in 2022 compared with 2021.<sup>11</sup> The WHO and UNICEF warn of serious outbreaks of vaccine-preventable illnesses.<sup>11</sup> School closure caused an increase in negative feelings in children. The length of school closure correlated with reported negative behavioral changes in children.<sup>12</sup>

From children's health aspect, particularly physical development and growth of children living in vulnerable households, the pandemic has contributed to worsening dietary nutrition due to reliance on cheap, shelf-stable food that is higher in calories and low in nutrient density; lacking access to free school meals; and high breastfeeding cessation rates.<sup>7</sup> Furthermore, social and economic restrictions, as well as school closures imposed by the pandemic, can lead to social isolation, irregular sleep patterns, a reduction in physical outdoor activities, and increased screen time that can all prevent children from growing to their full potential (Figure 1).<sup>13</sup>



**References:** 1. Center for Strategic & International Studies. Southeast Asia Covid-19 Tracker. Available at: <https://www.csis.org/programs/southeast-asia-program/projects/past-projects/southeast-asia-covid-19-tracker>. Accessed June 2022. 2. Asian Development Bank. Basic Statistics 2021. April 2021. Available at: <https://www.adb.org/publications/basic-statistics-2021>. Accessed June 2022. 3. Morgan PJ and Trinh LQ. Impacts of COVID-19 on households in ASEAN countries and their implications for human capital development. ADBI Working Paper 1226. 2021. Tokyo: Asian Development Bank Institute. Available: <https://www.adb.org/publications/impacts-covid-19-households-asean-countries>. Accessed June 2022. 4. Clarke J, Kipping R, Chambers S, et al. Impact of COVID-19 restrictions on preschool children's eating, activity, and sleep behaviours: A qualitative study. *BMJ Open* 2021;15:e051497. 5. Jha AK and Arora A. The neuropsychological impact of E-learning on children. *Asian J Psychiatr* 2020;54:102306. 6. Govender I, Rangiah S, Kaswa R, et al. Malnutrition in children under the age of 5 years in primary health care setting. *S Afr Fam Pract* (2004) 2021;63(1):5337. 7. Early Intervention Foundation. Growing up in the COVID-19 pandemic: An evidence review of the impact of pandemic life on physical development in the early years. November 2021. Available at: <https://www.eif.org.uk/report/growing-up-in-the-covid-19-pandemic-an-evidence-review-of-the-impact-of-pandemic-life-on-physical-development-in-the-early-years>. Accessed June 2022. 8. Mahmudiono T, Nindya TS, Andrias DR, et al. Household food insecurity as a predictor of stunted children and overweight/obese mothers (SCOWT) in urban Indonesia. *Nutrients* 2018;10(5):535. 9. Botteman H, Vahdat B, Jouault C, et al. Becoming a mother during COVID-19 pandemic: How to protect maternal mental health against stress factors. *Front Psychiatry* 2021;12:764207. 10. Monk C, Lugo-Candelas C, Trumpff C. Prenatal developmental origins of future psychopathology: Mechanisms and pathways. *Annu Rev Clin Psychol* 2019;15:317–344. 11. World Health Organization (WHO). UNICEF and WHO warn of perfect storm of conditions for measles outbreaks, affecting children. Available at: <https://www.who.int/news/item/27-04-2022-unicef-and-who-warn-of-perfect-storm-of-conditions-for-measles-outbreaks-affecting-children>. Accessed June 2022. 12. ACAPS. Global analysis of COVID-19 impact on education. Available at: <https://www.acaps.org/special-report/global-analysis-covid-19-impact-education>. Accessed June 2022. 13. de Araujo LA, et al. The potential impact of the COVID-19 pandemic on child growth and development: a systematic review. *J Pediatr (Rio J)* 2021;97(4):369–377.



# Impact of COVID-19 among SEANUTS II children

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The World Health Organization declared COVID-19 a pandemic on 11 March 2020,<sup>1</sup> and soon after, many countries, including the four SEANUTS II countries, went into lockdown. While this drastic measure helped to limit community transmission and protected lives, it also caused unprecedented social and economic disruptions that were equally harmful.<sup>1</sup> The SEANUTS II study was underway during this challenging period but presented an opportunity to evaluate the impact of COVID-19 on lifestyle behavior changes of the children and families of SEANUTS II.

Close to ten thousand children (n=9,680) between 6 months to 12.9 years were involved in the COVID-19 sub-study. Data collection for Malaysia (online survey) took place during the lockdown period. Interviews, either via the telephone (Indonesia) or face-to-face (Thailand and Vietnam), were conducted after lockdown and were based on recollection of events during the lockdown. The questionnaires focused on the following: socio-economic impact of COVID-19, child food habits, and physical activity status.

## Socio-economic impact

During the COVID-19 lockdown, a shift was observed from fewer parents/guardians working from the office to more of them working from home. This trend was most prominent in Malaysia for both female and male parents/guardians whereas in Indonesia this was not observed most likely due to the nature of work (office and blue-collar workers and >50% of the female parent/guardian were not working). There was also an increase in the proportion of parents not working either due to loss of job or retirement across all countries.

As a consequence, >44% of households reported a reduction in household income and 17% (Vietnam) to 38% (Indonesia) of households spend less on food. Malaysia was the exception with a 54% increase in food expenditure.

## Physical activity

On average, one-in-three children experienced a reduction in outdoor physical activity (Indonesia: 37%; Thailand: 32%; Vietnam: 26%); the majority had no change in physical activity during the pandemic. More than half of Thai children reported increased use of electronic devices while for most of the children in Indonesia and Vietnam no noticeable changes were observed.

## Children food habits

In Indonesia, Thailand, and Vietnam, the majority of the children reported no noticeable change in their food habits for the major food groups surveyed including consumption of processed food, sweetened beverages, and snacks during COVID-19. The recollection nature of the survey method may likely have influenced these findings. **Figure 1** shows the food habits changes in Malaysia.

More than half of Vietnamese children missed out on school meals and school milk programs during the pandemic. A similar proportion was observed among Thai children for school meals and to a lesser extent (20%) for school milk.

## Malaysia: A closer look

Comparison of food habits before and during the COVID-19 pandemic visualized a significant improvement in the diet quality of Malaysian children during lockdown with increased consumption of vegetables, fruits, eggs, and bread, and less intake of sweetened beverages and confectionery. This change in food habits is likely to be influenced by the physical presence of parents working from home.

Two concerning patterns emerged. One is the reduced intake of milk and other dairy products by the children during this period (**Figure 1**). Another, the increase (22% to 35%) of eating instant noodles at least once a week (p<0.001), although fewer children ate fast (p<0.001 vs before) or outside food (p<0.001 vs before) during the lockdown.

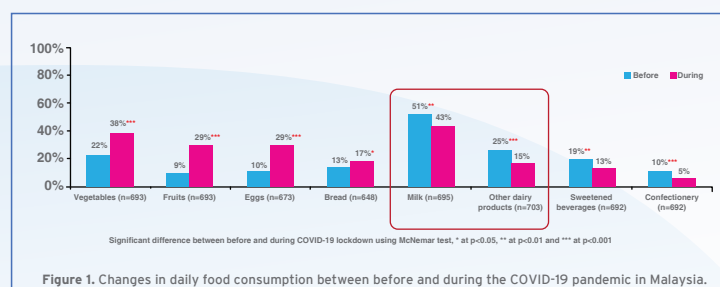


Figure 1. Changes in daily food consumption between before and during the COVID-19 pandemic in Malaysia.

For all children, COVID-19 lockdown led to a reduction in children's play space but the proportion of children meeting at least 1 hour of physical activity per day doubled (22% vs 11% p<0.001). For the 5-years-and-under group, there was a significant reduction in the proportion of children with at least 1 hour of energetic play per day and more children were in restraint for >1 hour at a time (16% vs 7%; p<0.05).

The COVID-19 sub-study has shed light on some of the positive and negative impacts of a lockdown on lifestyle behavior changes of SEANUTS II children and their families. Understanding these changes is important in helping public health authorities reshape future policies and food assistance programs that are both nutrition- and physical activity-focused.

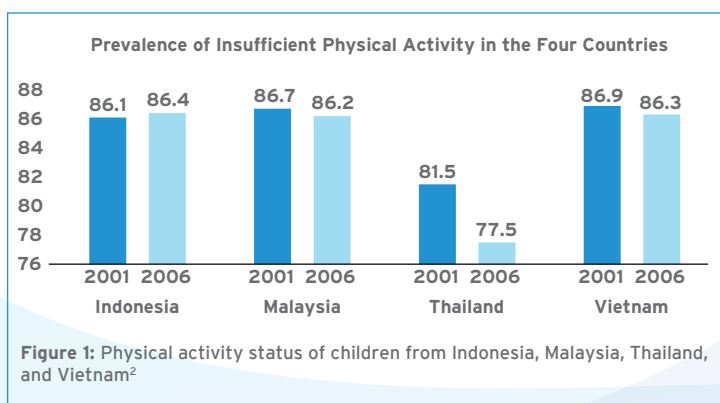
**References:** 1. World Health Organization. WHO Director-General's opening remarks at the media briefing on COVID-19 - 11 March 2020. Available at: <https://www.who.int/director-general/speeches/detail/who-director-general-s-opening-remarks-at-the-media-briefing-on-covid-19---11-march-2020>. Accessed June 2020.



# Physical activity of children in SEANUTS II: What, how, and why

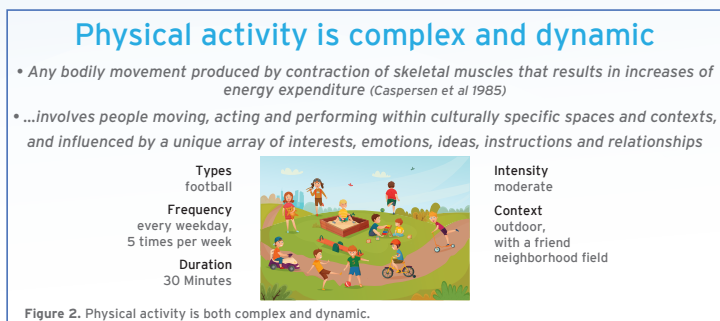
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The benefits of physical activity for children are robust, showing cardiorespiratory and muscular fitness, improved bone and cardiometabolic health, reduced adiposity, and better cognitive and academic performance with greater amount and higher intensity of physical activity.<sup>1</sup> Despite that, globally, 81% of adolescents have an insufficient level of physical activity.<sup>2</sup> The same trend was observed in Indonesia, Malaysia, Thailand, and Vietnam where the prevalence of insufficient physical activity among children was >70% (Figure 1).<sup>2</sup>



## SEANUTS II: What's new

The most widely accepted definition of physical activity is by Caspersen et al in 1985 and is defined as "any bodily movement produced by contraction of skeletal muscles that results in increases of energy expenditure".<sup>3</sup> A broader definition of physical activity has been proposed recently that emphasizes the holistic nature of physical activity, i.e., it is person-centered and may be influenced by the type of activity, the environment, the human experience, and social and cultural contexts (Figure 2).<sup>4</sup>



For SEANUTS II, physical activity is viewed as an important measure of nutrition survey because it allows measurement of energy expenditure and monitoring of trends and adherence to physical activity recommendations. Measuring physical activity in children can be challenging.<sup>5</sup> For one, play activities in children are typically sporadic and intermittent and consist of frequent, short bouts. Secondly, self-report methods of measurement may not sufficiently capture these short bouts of physical activity.

Therefore, in SEANUTS II, accelerometry was used in addition to the Physical Activity Questionnaire (PAQ) to capture the intensity and spontaneity of physical activity alongside the contextual information related to such activities in children. A subsample of SEANUTS II children was asked to wear the GENEActiv accelerometer on their non-dominant wrist for 7 consecutive 24-hour days to capture time spent in sleep, sedentary, and physical activity. GENEActiv is a lightweight, waterproof watch-like device that measures tri-axial (vertical, anteroposterior, and mediolateral) data, and can discriminate between physical activities of different intensities (sedentary, light, and moderate and above).<sup>6</sup> At the end of the 7 days, i.e., Day 8, the device was collected for data extraction and analysis.

To ensure continuity from SEANUTS I, age-specific PAQ<sup>7</sup> with summary questions was deployed to measure adherence to physical activity recommendations and also the type of planned and structured activities.

## What to expect

By combining two methods of assessments, SEANUTS II hopes to describe comprehensively the overall physical activity level of children, the types of structured activities, the intensity level of the different domains of activity, and the influence of physical activity on dietary intake and nutritional status.

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# Metabolomics in nutrition and food science

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Metabolomics describes the analysis of large sets of small molecules (metabolites) that exist in a biological system. All small molecules in a sample are defined as a metabolome but most techniques only measure a rather small subset of metabolites. At its most basic level, the human body can be viewed as an intricate network of metabolic processes (Figure 1) and the human metabolome is therefore an array of small molecule metabolites (peptides, lipids, amino acids, nucleic acids, carbohydrates, vitamins, minerals etc.) that all participate in numerous biological processes and are fundamental for proper growth and maintenance of all physiological functions.<sup>1</sup>

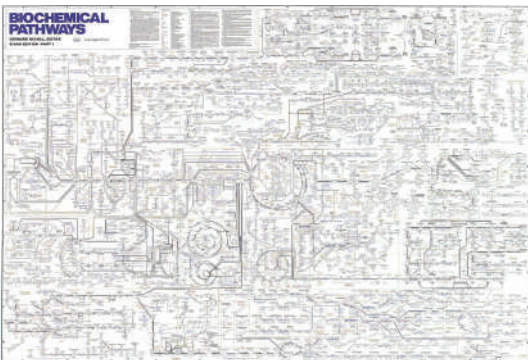


Figure 1: A map of the human metabolic pathways

## Metabolomics in nutrition science

The growing interest in integrating metabolomics into dietary and nutrition research is reflected by the exponential increase in scientific papers over the last decade.<sup>2</sup> There are three ways in which metabolomics can help us to understand the metabolic impact of diet and nutrition on human bodies and overall health.

**Dietary biomarkers.** Analysis of body fluids and biological tissues yields food-specific biomarkers that serve as indicators or signatures of certain dietary patterns and thus reflect food consumption.<sup>3</sup> Examples include 1-methylhistidine (diets rich in meat), phenylacetylglutamine (vegetable-rich diets), proline betaine (exposure to citrus fruits), dihydrocaffeic acid derivatives (coffee), and distinct phenolic metabolites (tomato).<sup>3</sup>

More recent evidence even suggests the possibility to measure quantitatively the levels of methylhistidines following consumption of different amounts of meat.<sup>4</sup> The same study also revealed that certain metabolites like trimethylamine-N-oxide and dimethylglycine can discriminate between beef (red meat) and chicken (white meat).<sup>4</sup>

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It must be noted that many of the food-origin biomarkers not only overlap with endogenous production but are also present in other food sources, hence the need for caution in data interpretation. Nevertheless, dietary markers may offer a more objective measure of diet and dietary patterns over classical questionnaire methods.<sup>4</sup>

**Metabolic phenotyping.** Metabolomics allows researchers to also compare metabolome profiles and distinguish based on this between healthy and diseased states and monitor over time the effect of dietary or pharmacological intervention.<sup>3</sup>

One such example is the evaluation of plasma polyphenols measured in huge cohorts and the context of colon cancer risk. Polyphenols can affect many body functions and are abundant in plant foods, and some are touted to have anti-cancer properties. However, the research by Murphy et al<sup>5</sup> showed that only two metabolite markers are clearly associated with colon cancer, with higher levels of equol (a metabolite from soy food) showing an inverse association with colon cancer risk while higher levels of homovanillic acid (a metabolite of dopamine-related metabolism) is associated with an increased colon cancer risk.

The development of diabetes is also another area that generated much interest in metabolomic studies with evidence that certain metabolite profiles (i.e., dominated by branch-chained and aromatic amino acids) are associated with a higher risk of diabetes development.<sup>6,7</sup> Nevertheless, further investigation is needed to evaluate the feasibility of using these "metabolite signatures" as an early diagnostic marker of diabetes development.<sup>8</sup>

**Knowledge-generating omics databases.** A direct additional effect of metabolomics is the sharing of research data through various omics databases (e.g., Human Metabolome Database, KEGG Pathway, BRENDA, Reactome, FoodDB, Phenol Explorer, PhytoHub).<sup>3,9-11</sup> These publicly accessible databases provide valuable information on the chemical structures of the metabolites; their biological properties; related metabolic pathway, occurrence and possible concentration in foods; and their effects on health. The databases also allow researchers to generate new insights on human metabolic pathways and their role in health or disease through multi-omics data integration and analysis.

To summarize, metabolomics is a promising tool to characterize the effects of diet and nutrition on human health with greater precision. Further investigative work and improvement on the current analytical platforms are needed for more precise data interpretation and possible application as diagnostic tools.



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