Seasonal variation in dietary diversity score and food variety score among an indigenous Karen population in western Thailand: a cross-sectional study

Pattamaporn Joompa[1], Sueppong Gowachirapant[1], Sinee Chotiboriboon[1], Rungnapha Sarasak[2], Nattapach Thongkam[1], Prapa Kongpunya[1], Wantanee Kriengsinyos[1,*]

[1]Institute of Nutrition, Mahidol University, Nakhon Pathom, Thailand
[2]Research Center for Nutrition Support, Faculty of Medicine Siriraj Hospital, Mahidol University, Bangkok, Thailand

***Corresponding author:** Wantanee Kriengsinyos, Mailing address: Institute of Nutrition, Mahidol University, 999 Phutthamonthon 4 Rd., Salaya, Phutthamonthon, Nakhon Pathom 73170, Thailand Tel. +66 (0) 2800-2380 Fax. +66 (0) 2441-9344, E-mail address: wantanee.krieng@mahidol.ac.th

Short title: Seasonal variation in dietary diversity of Karen population in western Thailand

Conflict of interest

There are no conflicts of interest.

Authorship

WK and SG designed the study and supervised the project. PJ, SG, SC, NT, and PK performed data collection. PJ and RS analyzed the data. PJ, SC, and RS conceptualized the manuscript. PJ drafted the manuscript. All authors reviewed the manuscript.

Ethical standards disclosure

This study was conducted according to the guidelines in the Declaration of Helsinki. All procedures involving research study participants were approved by the Center of Ethical Reinforcement for Research, Mahidol University (MUCIRB 2021/227.3004). Written informed consent was obtained from all subjects. The study protocol was also registered on the ClinicalTrials.gov platform at https://clinicaltrials.gov/ (identifier: NCT05930743).

Abstract

Objective: This study compared dietary diversity and nutrient adequacy across age groups and seasons within an indigenous Karen community.

Design: Cross-sectional survey.

Setting: Dietary intake was assessed using a single-day 24-hour dietary recall among Karen community members living in two villages of Laiwo subdistrict, Sangkhlaburi district, Kanchanaburi province, Thailand.

Participants: In total, 312 Karen people participated during the rainy season and 344 during the dry season, including school-age children (6-12 years), working-age people (19-59 years), and older people (≥60 years).

Results: Dietary diversity scores (DDS) and food variety scores (FVS) significantly differed across age groups for both seasons. However, seasonal DDS differences were not observed within any group, except for the FVS of school-age children. Over 70% of participants in all age groups had inadequate intake of key micronutrients—calcium, iron, vitamin A, vitamin C, zinc, vitamin B6, and vitamin B12—as indicated by nutrient adequacy ratios (NARs) < 0.75. Moderate to strong positive correlations between DDS and NARs for energy, vitamin B2, vitamin C, niacin, and mean adequacy ratio (MAR) (r = 0.418–0.691, $p < 0.001$) were observed exclusively in the dry season and across all age groups.

Conclusion: Among the Karen people, who are also facing triple burden malnutrition, dietary diversity is limited, micronutrient inadequacy is prevalent, and overall dietary quality is insufficient despite frequent vegetable consumption. Findings highlight the need to address systemic challenges related to food variety and to promote education on appropriate food quantities, preparation methods, and sustainable traditional food systems to improve nutrition.

Keywords: dietary diversity, school-age children, working-age people, older people, indigenous people

Introduction

Malnutrition remains a persistent global health and development concern and is a major barrier to achieving Sustainable Development Goals (SDGs) by 2030. It reflects critical shortcomings in both health and food security systems and is driven by a complex interplay of factors including inadequate food quantity, poor dietary quality, and socioeconomic inequality[1]. Ensuring nutritional adequacy is essential throughout the life course, as nutrient needs vary with age and physiological changes. A diet characterized by diversity and nutrient density is widely recommended to meet these dynamic needs[2]. However, imbalanced intake and impaired nutrient absorption can lead to persistent forms of malnutrition, most notably micronutrient deficiencies—particularly of iron, riboflavin, folate, and vitamin C—which remain prevalent globally and thus highlight the need to improve overall dietary quality[3].

Currently, several upper middle-income countries are facing a triple burden of malnutrition, marked by the simultaneous presence of overnutrition, undernutrition, and micronutrient deficiencies[4]. Evidence from the South East Asian Nutrition Surveys II (SEANUTS II) revealed that this nutritional complexity is increasingly evident across Thailand's population. While stunting remains prevalent primarily among infants and toddlers, the prevalence of overweight and obesity has increased significantly with age. Concurrently, inadequate intake of essential micronutrients—including calcium, iron, zinc, and vitamins A, C, and D—was found to be alarmingly high, affecting between 53.2% and 93.6% of individuals assessed[4]. These findings highlight the need for age-sensitive and context-specific strategies to address both nutritional deficits and excesses.

A key driver of this evolving nutritional landscape is an ongoing nutrition transition, characterized by a shift from traditional diets, which primarily rely on homegrown or foraged foods, to market-based diets rich in energy-dense and processed foods[5]. This shift has contributed to dietary imbalances, with increased intake of calories but reduced intake of essential nutrients. The effects of this transition are particularly profound among indigenous ethnic populations, whose food systems are closely intertwined with cultural identity, environmental sustainability, and local biodiversity. As these communities become increasingly integrated into a market economy, traditional food practices are disrupted and nutritional vulnerability increases, exacerbated by limited access to diverse, nutrient-rich foods[6]. Indigenous peoples also often face structural inequities, including limited access to basic healthcare and public services, which leads to their underrepresentation in national health statistics and research[7]. Beyond systemic marginalization, seasonal fluctuations in

food availability—driven by environmental cycles and climatic conditions—further compound the risks of food insecurity and malnutrition among these communities[2, 8].

In Thailand, the Karen people, the largest indigenous minority ethnic group, reside in rural and mountainous regions across the northern, central, and western provinces[9]. Due to the geographical isolation of their settlements and the predominant reliance on rotational farming alongside other agricultural practices, the Karen people remain largely dependent on localized, community-based food systems[10, 11]. Rooted in biodiversity, indigenous knowledge, and traditional wisdom, these food systems support a wide variety of food sources and culinary practices[11]. However, socioeconomic transformation, climate change, rural-to-urban migration, and the growing influence of modern dietary patterns have increasingly disrupted these systems. Consequently, changes in diet have contributed to lower nutrient intake and a rise in non-communicable diseases[11].

Although Thailand's Department of Health has established the Health Center for Ethnic Groups, Marginalized People, and Migrant Workers (HHDC) strategy to address health disparities at the policy level, comprehensive and disaggregated data on indigenous populations remain limited. While some studies have examined the food consumption behaviors of groups such as the Karen and Akha[12, 13], there remains a lack of clear research that explores the unique dietary patterns shaped by regional, ethnic, and cultural contexts—patterns that are crucial for understanding the nutritional challenges and needs of these communities[14].

To assess nutritional adequacy in diverse populations, the dietary diversity score (DDS) has been widely employed as a practical tool for assessing dietary quality. It is recognized for its simplicity, cost-effectiveness, and applicability across various populations and age groups[15, 16]. DDS is calculated based on the number of food groups consumed over a specific reference period, typically the preceding 24 hours, with higher DDS values generally indicating better dietary quality[15, 16]. In addition, the food variety score (FVS), which measures the number of individual food items consumed, serves as an additional non-invasive indicator of nutritional adequacy[17]. Both DDS and FVS have shown significant associations with nutritional adequacy across different age groups[18, 19]. These user-friendly and economical tools are extensively applied in nutritional assessments, particularly in resource-limited settings, and are especially relevant for evaluating vulnerable populations such as children, the elderly, pregnant women, indigenous groups, and migrant communities[20].

Accordingly, this study aimed to assess dietary diversity, food variety, and nutrient adequacy among the Karen people across three age groups—school-age children, working-age people, and older people—by comparing dietary intake between the rainy and dry seasons. This study also examined the correlation between the DDS and both the nutrient adequacy ratio (NAR) and the mean adequacy ratio (MAR). The findings are expected to inform the development of context-specific nutritional intervention strategies grounded in traditional food systems and local food security considerations.

Methods

Study design

This study is part of an international joint research project entitled Climate Change Resilience of Indigenous Socioecological Systems (RISE)[21]. A cross-sectional study was conducted in Laiwo subdistrict, Sangkhlaburi district, Kanchanaburi province, Thailand. This location is in Thungyai Naresuan National Wildlife Sanctuary in western Thailand, adjacent to the Myanmar border. Laiwo subdistrict consists of six Pwo Karen villages with similar lifestyles. Accessing these villages is quite difficult. During the dry season, they can be reached by four-wheel drive vehicle, but during the rainy season, they can only be reached by motorcycle or on foot. Consequently, only two villages near the district center were purposively selected for data collection.

Participants

Participants were categorized into three age groups: school-age children (6-12 years), working-age people (19-59 years), and older people (≥60 years). Population data for the two villages were collected in 2021 by public health volunteers, community leaders, and the local health-promoting hospital. The sample size for each village was calculated using the Taro Yamane formula[22]. After calculation and assuming a dropout rate of approximately 10%, a total of 78 school-age children, 300 working-age people, and 34 older people from the two villages were enrolled in this study.

Following the compilation of name lists, eligible participants were selected through simple random sampling for both villages. Inclusion and exclusion criteria were applied to ensure appropriate participant recruitment. Inclusion criteria were: 1) school-age children, working-age people, or older people who reside regularly in the two villages, 2) no history of mental illness as diagnosed by a doctor, and 3) neither serious medical conditions had been diagnosed by a doctor nor a therapeutic diet was advised. Exclusion criteria were: 1) participants with serious illnesses such as an accident or symptoms arising from a chronic

disease or other diseases during the period of data collection, and 2) participants who traveled outside the villages during the period of data collection.

Anthropometric measurements

Body weight and height were measured for all participant age groups following a standardized anthropometric procedure[23, 24]. Weight was measured using a Bioelectrical Impedance Analysis (BIA) (Tanita model BC-582), while height was measured using a portable stadiometer (Seca model 217). For school-age children (6-12 years), anthropometric status was determined according to the WHO growth reference for ages 5-19 years[25]. Z-scores for BMI-for-age (BAZ), height-for-age (HAZ), and weight-for-age (WAZ) were calculated using the WHO AnthroPlus version 1.0.4 software[26]. Underweight (5-10 years), stunting ($\geq$ 5 years), and wasting ($\geq$ 5 years) were defined as WAZ < -2 SD, HAZ < -2 SD, and BAZ < -2 SD, respectively. Overweight and obesity of children aged 5 years and above were defined as BAZ > 1 SD to $\leq$ 2 SD and BAZ > 2 SD, respectively. For working-age people (19-59 years) and older people ($\geq$ 60 years), BMI was calculated and categorized according to WHO classifications: underweight (< 18.5 kg/m^2), normal weight (18.5-24.9 kg/m^2), overweight (25-29.9 kg/m^2), and obese ($\geq$ 30 kg/m^2)[27].

24-hour dietary recall

Dietary intake was assessed using a single-day 24-hour dietary recall[28]. A pilot test was conducted with non-participating community members from similar food environments to ensure the tool's contextual relevance. Data were collected in two seasons: the rainy season (August 2022) and the dry season (February 2023). Trained researchers from the Institute of Nutrition, Mahidol University, conducted face-to-face interviews, during which participants were asked to recall all foods and non-alcoholic beverages consumed in the preceding 24 hours. Information collected included food types, ingredients, and estimated portion sizes. Local research assistants assisted with translation between the Thai and Karen languages to ensure clear communication. Guardians provided dietary information for school-age children when needed, including details on food preparation. School lunch menus—typically consisting of a main dish, fruit, and milk—were reviewed to verify food items that may have been omitted by child participants. To support recall accuracy, a food photo book was utilized containing 134 commonly consumed traditional foods, labeled in both the Thai and Karen languages. Nutritional information for food products purchased from local grocery stores was obtained from packaging labels.

Dietary diversity and food groups

The dietary diversity score (DDS) used in this study was adapted from the DDS endorsed by the Food and Agriculture Organization (FAO)[16] and the fifth Thai National Health Examination Survey to fit with the context of indigenous communities[29]. Dietary diversity was categorized into nine food groups based on an modified version of the DDS: 1) all starchy staples (cereals and tubers), 2) legumes, nuts, and seeds, 3) vegetables, 4) fruits, 5) flesh foods, 6) fish and seafood, 7) dairy and dairy products, 8) fat and oil, and 9) non-alcoholic beverages (e.g., fruit juices, soft drinks, energy drinks, soy milk, and other sweetened beverages). Consumption of $\geq$ 15 g/day from any food group was scored as 1 point; intake of < 15 g/day was scored as 0[30]. The total DDS ranged from 0 to 9, with higher scores indicating greater dietary diversity, as more food groups were consumed in adequate quantities ($\geq$ 15 g/day per group). Additionally, a food variety score (FVS) was calculated as a simple count of individual food items consumed across the nine food groups.

Nutrient intake and nutrient adequacy analysis

Daily nutrient intakes—including energy, protein, carbohydrates, fat, and ten selected micronutrients (calcium, iron, vitamin A, vitamin B1, vitamin B2, vitamin C, niacin, zinc, vitamin B6, and vitamin B12)—were estimated using INMUCAL-Nutrients V.4.0 software [31]. Nutrient adequacy was assessed as nutrient adequacy ratios (NARs), which reflect the sufficiency of an individual's intake for specific nutrients. NARs were calculated for 12 nutrients: energy, protein, calcium, iron, vitamin A, vitamin B1, vitamin B2, vitamin B6, vitamin B12, vitamin C, niacin, and zinc. Each NAR was derived by dividing a participant's daily intake of a given nutrient by its age- and sex-specific recommended nutrient intake (RNI)[32], based on the Thai Dietary Reference Intakes (DRIs) 2020[33]. The mean adequacy ratio (MAR) was computed by averaging all NAR values[32]. NAR or MAR values below 0.75 were considered indicative of inadequate nutrient intake[34-36]. To assess daily energy intake, the percentage of energy contribution from carbohydrates, protein, and fat was calculated and compared with the Acceptable Macronutrient Distribution Ranges (AMDRs): 45-65% for carbohydrates, 20-35% for fat, and 10-35% for protein[37].

Statistical analysis

Data analysis was performed using the SPSS version 21 statistical package (SPSS Corp., USA). Data normality was assessed using the Kolmogorov-Smirnov test. The continuous variables were presented as frequency, percentage, or means with standard deviations. The mean differences between groups were tested with One-Way ANOVA or Student's t-test as required. The Chi-square test was used to compare NAR and MAR between seasons. The Spearman correlation coefficient (r) was used to measure the correlation between DDS and

MAR. Statistical significance was considered at a two-tailed $p < 0.05$. Correlation strength was classified as strong ($r \geq 0.60$), moderate ($r = 0.40$–0.59), and weak ($r < 0.40$)[38, 39].

Results

Anthropometric characteristics

A total of 59 school-age children, 185 working-age people, and 40 older people from the two villages were assessed for body weight and height. The gender proportions between males and females were 26:33, 52:133, and 15:25 in school-age children, working-age people, and older people, respectively. The mean ages of school-age children, working-age people, and older people were 9.5 ± 1.9, 40.5 ± 11.2, and 67.5 ± 8.0 years old, respectively. The mean weights and heights of school-age children, working-age people, and older people were 33.1 ± 14.5 kg, 134.3 ± 13.5 cm; 57.5 ± 12.8 kg, 154.3 ± 6.9 cm; and 49.4 ± 11.1 kg, 152.4 ± 7.7 cm, respectively. Most school-age children had normal nutritional status. However, 5.1% were identified as stunted and thin, 8.5% were overweight, and 13.6% were obese. Likewise, only 8.1% of the working-age people were underweight. However, almost one-fourth of the working-age people were overweight (22.7%) and more than one-tenth were obese (11.4%). In the group of older people, approximately one-third were underweight (35.0%), while more than one-tenth were overweight (12.5%). Only 5% were obese (Table 1).

Seasonal variation in DDS and FVS

The DDS among the three participant groups ranged from 3.39 to 4.09 ($p < 0.05$) during the rainy season and from 3.41 to 4.43 ($p < 0.001$) during the dry season. Similarly, the FVS ranged from 5.67 to 7.09 ($p < 0.05$) and from 5.41 to 8.17 ($p < 0.001$) in the rainy and dry seasons, respectively. Among all age groups, older people consistently exhibited the lowest DDS and FVS in both seasons (Table 2). Between the two seasons and within each participant group, only the FVS of school-age children showed a statistically significant difference ($p < 0.05$) (Table 3). During the rainy season, the five most commonly consumed food groups across all participant groups included: 1) mainly rice (school-age children, 100%; working-age people, 99.0%; and older people, 100%), 2) vegetables (school-age children, 82.9%; working-age people, 97.6%; and older people, 91.7%), 3) meat, poultry, and eggs (school-age children, 67.1%; working-age people, 57.3%; and older people, 33.3%), 4) fat and oil (school-age children, 44.3%; working-age people, 78.2%; and older people, 33.3%), and 5) fish and seafood (school-age children, 35.7%; working-age people, 36.9%; and older people, 44.4%). However, the commonly consumed food groups during the dry season differed among the groups. Working-age people and older people mainly consumed:

1) rice (working-age people, 99.6%; older people, 100%), 2) vegetables (working-age people, 87.9%; older people, 79.5%), 3) meat, poultry, and eggs (working-age people, 70.6%; older people, 50.0%), 4) fish and seafood (working-age people, 49.8%; older people, 38.6%). For the fifth most commonly consumed food group, working-age people reported a higher intake of non-alcoholic beverages (33.3%), whereas older people consumed more fruits (27.8%). In contrast, school-age children commonly consumed: 1) rice (100%), 2) meat, poultry, and eggs (92.8%), 3) dairy and dairy products (62.3%), 4) vegetables (60.9%), and 5) non-alcoholic beverages (46.4%) (Figure 1).

Nutrient adequacy assessment

Nutrient adequacy ratios (NARs) for all selected nutrients and mean adequacy ratio (MAR) were calculated, with inadequacies identified using a cutoff of NAR and MAR < 0.75 (Table 4). Across both seasons, over two-thirds of the participants in all age groups had insufficient intakes of calcium, iron, vitamin A, vitamin C, zinc, vitamin B6, and vitamin B12. Older people exhibited a broader range of nutrient inadequacies during both seasons compared to school-age children and working-age people. Among school-age children, significant seasonal differences were observed in the inadequacy of protein, vitamin B2, niacin, and MAR. Among working-age people, significant differences between the rainy and dry seasons were found in the inadequate intake of energy, niacin, zinc, vitamin B6, and MAR. For older people, the only significant seasonal difference was zinc inadequacy. Energy intake and macronutrient distribution were also assessed (Supplementary Tables 2 and 3). The median energy intake of school-age children was 1,194.2 kcal/day in the rainy season (% energy distribution of carbohydrate:protein:fat = 63.1 : 10.6 : 24.9) and 1,240.5 kcal/day in the dry season (% of carbohydrate:protein:fat = 55.3 : 14.2 : 30.9). For working-age people, median energy intake was 1,415.4 kcal/day during the rainy season (% of carbohydrate:protein:fat = 72.7 : 10.7 : 15.6) and 1,094.3 kcal/day during the dry season (% of carbohydrate:protein:fat = 63.5 : 12.7 : 23.0). Among older people, energy intake was consistently low, with medians of 841.6 kcal/day in the rainy season (% of carbohydrate:protein:fat = 76.1 : 9.9 : 9.3) and 781.8 kcal/day in the dry season (% of carbohydrate:protein:fat = 68.5 : 10.5 : 17.2).

Nutrient adequacy ratio and correlation with dietary diversity score

Correlations between the NARs and MAR of all selected nutrients and the DDS across age groups during the rainy and dry seasons are presented in Table 5. Most significant moderate to strong positive correlations between DDS and both individual NARs and MAR were observed exclusively in the dry season across all age groups, particularly for NARs of energy, vitamin B2, vitamin C, and niacin (r = 0.418–0.691, $p < 0.001$). Across both seasons, older

people exhibited a greater number of significant moderate to strong correlations (r = 0.446–0.734, p < 0.001) between DDS and nutrient adequacy compared to the other age groups, particularly for the NARs of energy, protein, calcium, iron, vitamin B2, and the MAR. In contrast, only moderate correlations were observed between DDS and the NAR for energy (r = 0.418–0.469, p < 0.001) in school-age children, and between DDS and the NAR for protein (r = 0.442–0.559, p < 0.001) in working-age people during both seasons.

Discussion

Our study has revealed that the Karen people residing in rural western Thailand are facing a triple burden of malnutrition wherein overweight/obesity, undernutrition, and micronutrient deficiencies coexist despite the year-round availability of diverse traditional food sources. To our knowledge, this study is also the first to examine the effects of seasonality on DDS and FVS across different age groups among Karen communities. School-age children had higher DDS compared to working-age and older people, largely due to the higher intake of dairy products and non-alcoholic beverages. However, significant seasonal variation was observed only in FVS among school-age children, while DDS remained consistent across seasons and age groups. Moderate to strongly positive correlations were observed exclusively in the dry season across all age groups between DDS and the NARs for energy, vitamin B2, vitamin C, niacin, as well as MAR (r = 0.418–0.691, p < 0.001). Notably, across both seasons, older people demonstrated a higher number of significant moderate to strong correlations between DDS and NARs than the other age groups, particularly for the NARs of energy, protein, calcium, iron, vitamin B2, and the MAR (r = 0.446–0.734, p < 0.001). This finding highlights a critical nutritional gap for these communities.

Most notably, the average energy intake among participants, particularly older people, was relatively low (<1000 kcal/day) and at the lower end or below the national median reported among Thai older adults (male: 1004.5–1242.7 kcal/day; female: 928.5–1045.3 kcal/day)[40]. Additionally, over 35% of older participants were underweight, compared to 10.8% in the national survey of Thai adults aged over 60 years[29]. While calorie intake is not entirely correlated with Body Mass Index (BMI), factors such as physical activity, nutrient density, and basal metabolic rate must also be considered[41]. Nonetheless, the high prevalence of underweight and low FVS among older adults in this study suggests limited dietary diversity, which may contribute to insufficient energy intake.

Previous research documented that the Karen living in Sanephong village and included in the present study relied on more than 387 traditional food species sourced from

natural environments and cultivation, with many indigenous foods identified as rich sources of vitamins and minerals[11]. However, the global transition towards Western dietary patterns has been linked to rising malnutrition among indigenous populations[42, 43], as reflected in the nutritional challenges observed within the studied Karen communities. This trend is also consistent with the broader malnutrition situation in Thailand[4, 44].

To evaluate dietary patterns in the Karen community across seasons, this study adapted the DDS guidelines endorsed by the FAO[16] and classifications from the Fifth Thai National Health Examination Survey[29]. The food groups were modified to reflect the Karen socioecological context. Within each season, significant differences in DDS and FVS were observed among the three age groups, with school-age children showing higher DDS, primarily due to greater consumption of dairy products and non-alcoholic beverages. However, no significant differences in DDS were observed between the two seasons in all three age groups. Only the FVS of school-age children significantly differed between rainy and dry seasons. This contrasts with prior studies showing clear seasonal effects on DDS[45, 46]. Although seasonality has been widely explained as a factor influencing dietary diversity and nutrient adequacy, it may not be generalizable to all populations in different communities with distinct socioecological factors, such as socioeconomic status, ecosystem, topography, climate, cultural background, and traditional wisdom[46].

Although age groups differed in DDS and FVS within seasons, overall FVS ranged only from 5.67 to 8.17, which is relatively low compared to previous reports of 14 to 20[19]. Traditional meal patterns remain prevalent, with most Karen families consuming two meals daily, typically consisting of chili paste with vegetables, soups, fried foods, and curries[11]. Furthermore, a previous study by Chotiboriboon et al. found iron-rich food sources in a Karen community, including a type of snail called *Khlu-mi* and *Bai-ma-ngua* (Citrus medica L. var. medica) (dark green leaves)[11]. However, according to local people, *Khlu-mi* is now rare due to flooding in the villages in 2018. This exemplifies how natural disasters—linked to climate change, and described by WHO as the "defining issue" for 21st-century public health[47]—threaten traditional food systems and warrants further study.

Interestingly, although vegetables were commonly consumed across all age groups, the intake of vitamins A and C remained insufficient, most likely attributable to both suboptimal portion sizes and high heat cooking methods[48]. For instance, vegetables high in vitamins A and C, such as *Pak-man-mu* or *Le-khawng-du* (*Gnetum nemon* L. var. tenerum Markr.) (dark green leaves), *Yawd-fak-kao* (*Momordica chochinchinensis* Spreng) (young leaves), and *Bai-ma-ngua* (*Citrus medica* L. var. *medica*) (dark green leaves), were regularly

included in meals, but may not have been consumed in sufficient quantities to meet daily nutrient requirements. Similarly, *Bai-ma-ngua* (*Citrus medica* L. var. *medica*), a rich source of vitamins C and A, iron, and calcium, was available but did not appear to contribute adequately to overall nutrient intake. Moreover, the widespread practice of boiling vegetables—particularly among older adults who tend to retain traditional food preparation habits—likely further reduces the bioavailability of water-soluble and heat-labile nutrients, including vitamin C and some B vitamins.

The DDS in this study used a threshold of ≥15 g/day to count food items, reflecting both quantity and quality of intake. This approach underscores that seasonal variation in food availability may not be the primary driver of nutritional status in these Karen communities, as a range of traditional foods—including rice, vegetables, fruits, and fish—are available throughout the year. Instead, other factors such as socioeconomic status, cultural norms, environmental changes, and cooking practices appear more influential in shaping dietary quality and nutrient adequacy[46].

These findings underscore the need to preserve traditional food systems and cultural dietary practices while addressing persistent nutrient gaps through culturally appropriate interventions. The vulnerability of indigenous food sources to climate change and environmental disruptions further threatens food security and health outcomes. Moreover, socioeconomic transitions—such as increased wage labor, government employment, and labor migration—have contributed to higher household incomes and food purchasing expenditures compared to earlier reports[11], marking a shift from a traditional to a mixed food system[49]. This transition may reduce reliance on diverse indigenous foods and increase dependence on market-based products, with potential implications for diet quality and nutritional status. Future research should explore the detailed contribution of traditional versus market foods to dietary intake, as well as investigate strategies to promote nutrient retention during food preparation and to enhance access to diverse, nutrient-rich foods year-round.

Strengths and limitations

A key strength of this study lies in its investigation of nutrient adequacy and dietary diversity across different age groups—school-age children, working-age people, and older people—within Karen communities and across two distinct seasons. Notably, one of the two Karen villages included in this study was also examined in 2009[11], allowing for comparative insights into the ongoing transition of traditional food systems. Furthermore, the use of the

INMUCAL software, which incorporates a database of Thai foods along with selected Karen food items, provided a culturally relevant and context-specific approach to estimating dietary intake.

However, several limitations may have impacted this study and should be kept in mind for future research. First, dietary intake data were collected using a single-day 24-hour dietary recall, which may not fully capture individuals' habitual diets or the typical variety of foods consumed. Second, during the rainy season—coinciding with the beginning of the planting season—many working-age people and some school-age children accompanied their families to upland rice swidden areas located far from the village, often for several days or weeks. This seasonal migration resulted in a lower number of participants than originally calculated for the sample size. Third, most school-age children were interviewed on weekends due to difficulties in conducting interviews after school on weekdays, such as continuous rainfall during the rainy season and limited lighting which relied on solar panels. In contrast, dietary interviews during the dry season were more evenly distributed between weekdays and weekends. This discrepancy may have influenced the reported frequency of certain food group consumption, especially milk, which is more likely to be consumed at school. Finally, limitations in the INMUCAL software database—particularly for zinc, vitamin B6, and vitamin B12—may have led to underestimations of actual nutrient intakes[31].

Conclusion

This study highlights the coexistence of traditional and modern dietary patterns among the Karen people and the nutritional challenges that arise from this transition. Despite year-round access to diverse food sources, micronutrient inadequacies—particularly among older people—persist, while increasing market food consumption, especially among school-age children, reflects the broader nutrition transition. Age- and season-specific variations in dietary variety underscore the complex interplay of cultural practices, food access, and environmental factors. These findings emphasize the need for culturally sensitive interventions that strengthen traditional food systems, improve food preparation practices to retain nutrient quality, and support sustainable strategies to enhance dietary diversity and nutritional adequacy across all age groups.

References

1. Food and Agriculture Organization, International Fund for Agricultural Development, United Nations Children's Fund, World Food Programme & World Health Organization (2024) *The State of Food Security and Nutrition in the World 2024: Financing to End Hunger, Food Insecurity and Malnutrition in All Its Forms*. Rome: FAO.

2. Bryson JM, Patterson K, Berrang-Ford L et al. (2021) Seasonality, climate change, and food security during pregnancy among Indigenous and non-Indigenous women in rural Uganda: Implications for maternal–infant health. *PLoS One* 16, e0247198.

3. Passarelli S, Free CM, Shepon A et al. (2024) Global estimation of dietary micronutrient inadequacies: a modelling analysis. *Lancet Glob Health* 12, e1590–e1599.

4. Pongcharoen T, Rojroongwasinkul N, Tuntipopipat S et al. (2024) South East Asian Nutrition Surveys II (SEANUTS II) Thailand: triple burden of malnutrition among Thai children aged 6 months to 12 years. *Public Health Nutr* 27, e152.

5. Khandelwal S & Kurpad A (2019) A vision for nutrition research in Asia. *Food Nutr Bull* 40, 133–142.

6. Pesantes MA, Bazan Macera M, Mercier S et al. (2024) Healthy food, unhealthy food: Indigenous perspectives on the nutrition transition. *Glob Public Health* 19, 2329210.

7. Reid P, Spoonley J, Jones R et al. (2021) The health of Indigenous peoples. In *Oxford Textbooks of Global Public Health*, 7th ed., Oxford: Oxford Academic.

8. Vaitla B, Devereux S & Swan SH (2009) Seasonal hunger: a neglected problem with proven solutions. *PLoS Med* 6, e1000101.

9. Premsrirat S (2004) *Ethnolinguistic Maps of Thailand*. Bangkok: Ministry of Culture and Mahidol University.

10. Suhardiman D, Care C & Kaw SN (2025) A Karen Indigenous approach to food sovereignty: tracing processes of institutional emergence. *Geoforum* 159.

11. Chotiboriboon S, Tamachotipong S, Sirisai S et al. (2009) Thailand: food system and nutritional status of indigenous children in a Karen community. In *Indigenous Peoples' Food Systems: The Many Dimensions of Culture, Diversity and Environment for Nutrition and Health*, pp. 158–183.

12. Sroywong D, Wong J & Thongprachum A (2022) Food consumption behavior among ethnic minority pre-school children in Mae Chaem District, Chiang Mai Province, Thailand. *Thai J Public Health* 52, 103–112.

13. Muangmool J, Pattanawiboon K, Manotham M et al. (2017) Food consumption behavior and health status of Akha in Mae Suai District, Chiang Rai Province. *J Soc Acad* 10, 186–195.

14. Sproesser G, Ruby MB, Arbit N et al. (2022) Similar or different? Comparing food cultures with regard to traditional and modern eating across ten countries. *Food Res Int* 157, 111106.

15. Rathnayake KM, Madushani P & Silva K (2012) Use of dietary diversity score as a proxy indicator of nutrient adequacy of rural elderly people in Sri Lanka. *BMC Res Notes* 5, 469.

16. Food and Agriculture Organization (2011) *Guidelines for Measuring Household and Individual Dietary Diversity*. Rome: FAO.

17. Hodgson JM, Hsu-Hage BH & Wahlqvist ML (1994) Food variety as a quantitative descriptor of food intake. *Ecol Food Nutr* 32, 137–148.

18. Oldewage-Theron WH & Kruger R (2008) Food variety and dietary diversity as indicators of the dietary adequacy and health status of an elderly population in Sharpeville, South Africa. *J Nutr Elder* 27, 101–133.

19. Vispute S, Mandlik R, Sanwalka N et al. (2023) Dietary diversity and food variety scores and their association with nutrition and health status of Indian children and adolescents: a multicenter study. *Nutrition* 111, 112039.

20. Ruel MT (2003) Operationalizing dietary diversity: a review of measurement issues and research priorities. *J Nutr* 133, 3911S–3926S.

21. Garcia Molinos J, Gavrilyeva T, Joompa P et al. (2022) Study protocol: International joint research project 'climate change resilience of Indigenous socioecological systems' (RISE). *PLoS One* 17, e0271792.

22. Yamane T (1973) *Statistics: An Introductory Analysis*, 3rd ed. New York: Harper and Row.

23. World Health Organization (2008) *Training Course on Child Growth Assessment, WHO Child Growth Standards*. Geneva: WHO.

24. Lohman T, Roche AF & Martorell R (1988) *Anthropometric Standardization Reference Manual*. Champaign, IL: Human Kinetics Books.

25. de Onis M, Onyango AW, Borghi E et al. (2007) Development of a WHO growth reference for school-aged children and adolescents. *Bull World Health Organ* 85, 660–667.

26. World Health Organization (2009) *WHO AnthroPlus for Personal Computers Manual: Software for Assessing Growth of the World's Children and Adolescents*. Geneva: WHO.

27. World Health Organization (1995) *Physical Status: The Use and Interpretation of Anthropometry*. Report of a WHO Expert Committee. *WHO Tech Rep Ser* 854, 1–452.

28. Baranowski T (2012) 24-hour recall and diet methods. In *Nutritional Epidemiology*, 3rd ed., pp. 547. Oxford: Oxford University Press.

29. Chalermsri C, Rahman SM, Ekstrom EC et al. (2023) Dietary diversity predicts the mortality among older people: data from the fifth Thai National Health Examination Survey. *Arch Gerontol Geriatr* 110, 104986.

30. Food and Agriculture Organization (2021) *Minimum Dietary Diversity for Women: An Updated Guide to Measurement – from Collection to Action*. Rome: FAO.

31. Institute of Nutrition, Mahidol University (2018) *Nutrient Calculation Computer Software INMUCAL–Nutrients V.4.0*. Nakhon Pathom: Mahidol University.

32. Akter R, Yagi N, Sugino H et al. (2020) Household engagement in both aquaculture and horticulture is associated with higher diet quality than either alone. *Nutrients* 12, 1156.

33. Chaengbumrung S, Mo-suwan L, Phonrat B et al. (2020) *Dietary Reference Intake for Thais 2020*, 1st ed. Bangkok: Bureau of Nutrition, Department of Health, Ministry of Public Health.

34. Soh SM, Chung SJ & Yoon J (2020) Dietary and health characteristics of Korean adults according to the level of energy intake from carbohydrate: analysis of the 7th (2016–2017) Korea National Health and Nutrition Examination Survey data. *Nutrients* 12, 2025.

35. Koszewski WM, Behrends D, Nichols MJ et al. (2011) Patterns of family meals and food and nutrition intake in limited-resource families. *Fam Consum Sci Res J* 39, 431–441.

36. Menber Y, Gashaw S, Belachew T et al. (2024) Validation of the minimum dietary diversity for women as a predictor of micronutrient adequacy among lactating women in Ethiopia. *Front Nutr* 11, 1459041.

37. Trumbo P, Schlicker S, Yates AA et al. (2002) Dietary reference intakes for energy, carbohydrate, fiber, fat, fatty acids, cholesterol, protein and amino acids. *J Am Diet Assoc* 102, 1621–1630.

38. Steyn NP, Nel JH, Nantel G et al. (2006) Food variety and dietary diversity scores in children: are they good indicators of dietary adequacy? *Public Health Nutr* 9, 644–650.

39. Akoglu H (2018) User's guide to correlation coefficients. *Turk J Emerg Med* 18, 91–93.

40. National Health Examination Survey Office (2011) *Thai Food Consumption Survey: The Fourth National Health Examination Survey 2008–2009*. Nonthaburi: Ministry of Public Health.

41. World Health Organization (2000) *Obesity: Preventing and Managing the Global Epidemic. Report of a WHO Consultation*. *WHO Tech Rep Ser* 894. Geneva: WHO.

42. Lam RD, Huynh LTM, Lozano Lazo DP et al. (2023) Diet change and sustainability in Indigenous areas: characteristics, drivers, and impacts of diet change in Gunayala, Panama. *Sustain Sci*, 1–23.

43. Fernandez CI (2020) Nutrition transition and health outcomes among Indigenous populations of Chile. *Curr Dev Nutr* 4, nzaa070.

44. Department of Health (2024) *Health Promotion and Environmental Health Surveillance Annual Report 2023*. Nonthaburi: Ministry of Public Health, Thailand.

45. Guizzo Dri G, Spencer PR, da Costa R et al. (2022) The seasonal relationships between household dietary diversity and child growth in a rural Timor-Leste community. *Matern Child Nutr* 18, e13363.

46. Fujihira K, Takahashi M, Wang C et al. (2023) Factors explaining seasonal variation in energy intake: a review. *Front Nutr* 10, 1192223.

47. Benevolenza MA & DeRigne L (2018) The impact of climate change and natural disasters on vulnerable populations: a systematic review of literature. *J Hum Behav Soc Environ* 29, 266–281.

48. Anisong N, Siripongvutikorn S, Wichienchot S et al. (2022) A comprehensive review on nutritional contents and functional properties of *Gnetum gnemon* Linn. *Food Sci Technol* 42.

49. High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security (2017) *Nutrition and Food Systems*. Rome: FAO.
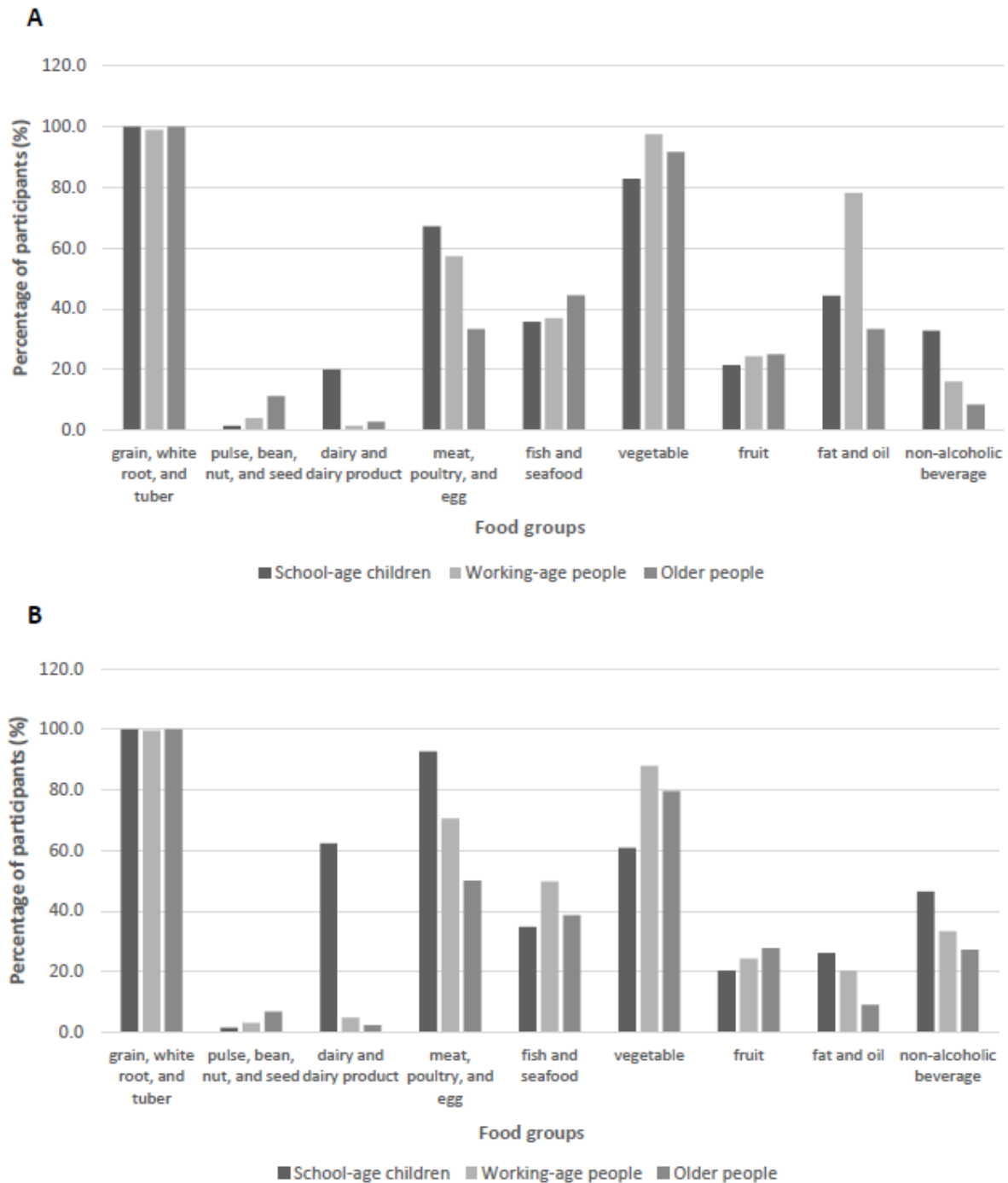
Figure 1. Percentage of participants in each age group consuming each food group during the rainy season (A) and the dry season (B).

Table 1. Nutritional status of participants (n = 284).

	School-age children (n = 59)	Working-age people (n = 185)	Older people (n = 40)
Age, y	9.5 ± 1.9	40.5 ± 11.2	67.5 ± 8.0
Gender			
male:female, n:n	26 : 33	52 : 133	15 : 25
Height, cm	134.3 ± 13.5	154.3 ± 6.9	152.4 ± 7.7
Weight, kg	33.1 ± 14.5	57.5 ± 12.8	49.4 ± 11.1
BMI, kg/m^2	-	24.1 ± 5.0	20.9 ± 4.0
BAZ	0.1 ± 1.4	-	-
HAZ	-0.2 ± 1.1	-	-
WAZ (n=39, >10 Y)	-0.1 ± 1.4	-	-
Stunting (n, %)	3, 5.1	-	-
Wasting (n, %)	3, 5.1	-	-
Underweight (n, %)	-	15, 8.1	14, 35.0
Overweight (n, %)	5, 8.5	42, 22.7	5, 12.5
Obesity (n, %)	8, 13.6	21, 11.4	2, 5.0

Values are mean ± SD

BAZ, body-mass-index (BMI)-for-age

WAZ, weight-for-age Z score

HAZ, height-for-age Z score

Table 2. Dietary diversity scores (DDS) and food variety scores (FVS) by participant group and season.

	n	DDS	*p*	FVS	*p*
Rainy season					
School-age children	70	4.09 ± 1.29		6.90 ± 3.08	
Working-age people	206	3.91 ± 1.21	0.021*	7.09 ± 3.16	0.042*
Older people	36	3.39 ± 1.20		5.67 ± 2.83	
Dry season					
School-age children	69	4.43 ± 1.14		8.17 ± 2.88	
Working-age people	231	3.93 ± 1.17	< 0.001*	6.93 ± 3.26	< 0.001*
Older people	44	3.41 ± 1.30		5.41 ± 2.60	

Values are mean ± SD

p values were calculated using One-Way ANOVA

* $p < 0.05$

Table 3. Comparison of dietary diversity scores (DDS) and food variety scores (FVS) between the rainy and dry seasons for each participant group.

	DDS			FVS		
	Rainy	**Dry**	*p*	**Rainy**	**Dry**	*p*
School-age children	4.09 ± 1.29	4.43 ± 1.14	0.094	6.90 ± 3.08	8.17 ± 2.88	0.013*
Working-age people	3.91 ± 1.21	3.93 ± 1.17	0.840	7.09 ± 3.16	6.93 ± 3.26	0.601
Older people	3.39 ± 1.20	3.41 ± 1.30	0.943	5.67 ± 2.83	5.41 ± 2.60	0.673

p values were calculated using independent t-test.

* $p < 0.05$

Table 4. Percentage of participants with inadequate nutrient intake (nutrient adequacy ratio (NAR) and mean adequacy ratio (MAR) < 0.75).

Nutrient	School-age children, n (%)			Working-age people, n (%)			Older people, n (%)		
	Rainy (n = 70)	Dry (n = 69)	*p*	Rainy (n = 206)	Dry (n= 231)	*p*	Rainy (n= 36)	Dry (n = 44)	*p*
Energy	38 (54.3)	34 (49.3)	0.674	111 (53.9)	156 (67.5)	0.003*	28 (77.8)	34 (77.3)	0.957
Protein	24 (34.3)	6 (8.7)	< 0.001**	110 (87.4)	140 (60.6)	0.128	27 (75.0)	37 (84.1)	0.312
Calcium	69 (98.6)	67 (97.1)	0.551	180 (80.1)	201 (87.0)	0.909	35 (97.2)	41 (93.2)	0.409
Iron	57 (81.4)	51 (73.9)	0.287	165 (80.1)	185 (80.1)	0.998	32 (88.9)	40 (90.9)	0.764
Vitamin A†	63 (90.0)	58 (84.1)	0.297	172 (83.5)	197 (85.3)	0.607	34 (94.4)	37 (84.1)	0.145
Vitamin B1	37 (52.9)	29 (42.0)	0.201	114 (55.3)	144 (62.3)	0.138	27 (75.0)	34 (77.3)	0.812
Vitamin B2	50 (71.4)	24 (34.8)	< 0.001**	159 (77.2)	188 (81.4)	0.278	34 (94.4)	41 (93.2)	0.816
Vitamin C	54 (77.1)	56 (81.2)	0.560	147 (71.4)	172 (74.5)	0.446	33 (91.7)	40 (90.9)	0.905
Niacin	33 (47.1)	16 (23.2)	0.003*	76 (36.9)	160 (69.3)	< 0.001**	24 (66.7)	35 (79.5)	0.193
Zinc	64 (91.4)	64 (92.8)	0.772	168 (81.6)	221 (95.7)	< 0.001**	32 (88.9)	44 (100)	0.023*
Vitamin B6	60 (85.7)	62 (89.9)	0.456	159 (77.2)	218 (94.4)	< 0.001**	33 (91.7)	44 (100)	0.051
Vitamin B12	64 (91.4)	59 (85.5)	0.274	198 (96.1)	214 (92.6)	0.118	35 (97.2)	42 (95.5)	0.679
MAR	51 (72.9)	38 (55.1)	0.029*	151 (73.3)	191 (82.7)	0.018*	31 (86.1)	40 (90.9)	0.499

p values were calculated using Chi-Square test.

* $p < 0.05$, ** $P < 0.001$

†Retinol activity equivalent (RAE), 1 RAE = 1 μg retinol, 12 mg β-carotene, 24 mg α-carotene, or 24 mg β-cryptoxanthin

Table 5. Nutrient adequacy ratios (NARs) and mean adequacy ratio (MAR) according to dietary diversity score (DDS).

Nutrient	DDS					
	School-age children		Working-age people		Older people	
	Rainy (n = 70)	Dry (n = 69)	Rainy (n = 206)	Dry (n= 231)	Rainy (n= 36)	Dry (n = 44)
Energy, kcal	0.469**	0.418**	0.241**	0.497**	0.452**	0.682**
Protein, g	0.505**	0.365**	0.442**	0.559**	0.515**	0.734**
Calcium, mg	0.382**	0.387*	0.331**	0.464**	0.644**	0.529**
Iron, mg	0.290*	0.243*	0.249**	0.405**	0.585**	0.720**
Vitamin A[†], µg	0.406**	0.217	0.248**	0.347**	0.454**	0.286
Vitamin B1, mg	0.217	0.279*	0.245**	0.355**	0.345*	0.580**
Vitamin B2, mg	0.386*	0.443**	0.363**	0.506**	0.565**	0.625**
Vitamin C, mg	0.196	0.510**	0.102	0.443**	0.174	0.610**
Niacin, mg	0.270	0.490**	0.146*	0.420**	0.146	0.484**
Zinc, mg	0.152	0.393**	0.204*	0.382**	0.151	0.557**
Vitamin B6, mg	0.130	0.244*	0.117	0.220**	-0.005	0.299*
Vitamin B12, µg	0.309*	-0.023	0.514**	0.286**	0.340*	0.154
MAR	0.058**	0.466**	0.330**	0.521**	0.446**	0.691**

Spearman correlation coefficients were calculated to assess the association between DDS and each of the NARs as well as the MAR.

* $p < 0.01$, ** $P < 0.001$

†Retinol activity equivalent (RAE), 1 RAE = 1 µg retinol, 12 mg β-carotene, 24 mg α-carotene, or 24 mg β-cryptoxanthin