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Dietary Intake and Micronutrient Adequacy among Adults in Rural Sri Lanka: Findings from a Cross-Sectional Baseline Survey

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Ethical Standards Disclosure: This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving research study participants were approved by the Ethics Review Committee at the Wayamba University of Sri Lanka and the Institutional Review Board at the International Food Policy Research Institute. Verbal informed consent was obtained from all subjects/patients. Verbal consent was witnessed and formally recorded.

Abstract

Objective. To characterize food group consumption, assess the contribution of food groups to energy and micronutrient intake, and estimate usual nutrient intake among adults in rural Sri Lanka.

Design. A baseline survey (Dec 2020–Feb 2021) was conducted as part of an agriculture-based, nutrition-sensitive resilience program evaluation. Dietary intake was assessed using telephone-based 24-hour recalls (n=1283), with repeat recalls from 769 participants. Mean daily intake of food groups and their contribution to energy and nutrient intakes were calculated. The National Cancer Institute method was used to estimate usual intakes and the prevalence of adequate micronutrient intake (PAI). Differences by sex, district, and wealth were assessed using t-tests and ANOVA.

Setting. Forty-five rural villages throughout Sri Lanka.

Participants. Men and women from households in the program evaluation study area.

Results. On average, grains and coconut milk provided 56% and 12% of energy, respectively. Rice, fish, dairy, and pulses were the primary sources of micronutrients. Participants consumed 118±117g vegetables and 71±243g fruit per day. PAI was <25% for calcium; zinc; niacin; folate; and vitamins B6, B12, and C, reflecting low consumption of animal-source foods (ASF; 80 g/day), whole grains, fruits, and vegetables (F&V). Significant differences in food group consumption by sociodemographic subgroup were observed among districts and wealth quintiles.

Conclusions. We observed high consumption of rice and coconut milk and low prevalence of micronutrient adequacy. We recommend increasing ASF, whole grain, and F&V consumption to close nutrient gaps, as well as research to identify effective solutions to increase micronutrient intake.

Key words: diet assessment, prevalence of adequacy, micronutrient intake, fruit and vegetables

Introduction

Healthy diets are critical for preventing disability and chronic diseases, and for optimal human functioning across the lifespan. Fruit and vegetables (F&V) are particularly important for protection against cancer, metabolic diseases, and cardiovascular diseases.(1) Individual-level dietary data are needed to better understand food group and micronutrient intake in low and middle income countries (LMICs).

In 2021, the Sri Lanka Ministry of Health published a revision to the national food-based dietary guidelines (FBDG), which recommend that half of the diet come from unrefined grains, cereals, and starchy staples, one third from vegetables, and the remainder from protein-rich foods.(2) The guidelines also recommend that adults consume ≥3 servings of vegetables and ≥2 servings of fruit per day. Despite this guidance, dietary patterns in Sri Lanka include high consumption of cereals and low consumption of micronutrient-dense foods, including meat, eggs, nuts, seeds, dairy, dark leafy greens, and deep orange F&V.(3,4) Rice is the leading source of calories, and only 25% of Sri Lankan adults consume at least the recommended 5 F&V servings/day, which places individuals at risk of micronutrient deficiency.(3-5) Animal source food (ASF) intake is also low in Sri Lanka, which may be due in part to cultural and religious preferences towards plant-based diets.(6) Based on 2013 food balance sheet estimates, at least one third of Sri Lankans were at risk of folate, zinc, and vitamin B12 inadequacy, and nearly the entire population was at risk of inadequate calcium and riboflavin intake.(7) While previous research offers some understanding of food group consumption among Sri Lankans, statistically rigorous evidence on nutrient intake and prevalence of adequate micronutrient intake is lacking, particularly among women outside of childbearing years and men of any age.(3-5)

National estimates from 2022 suggest that 8.2% and 18.5% of Sri Lankan men and women experienced anemia, respectively, while 2.5% and 7.2% were iron deficient.(8) Nationally representative data regarding other micronutrient deficiencies in Sri Lanka is lacking. In addition to micronutrient deficiencies, the country is undergoing a transition toward calorie-dense, nutrient-poor, ultra-processed foods, increasing the risk of obesity and chronic diseases.(9–11) The prevalence of obesity and overweight are estimated to have doubled between 2000 and 2019 –

from 18% to 30% among women and from 11% to 20% among men.(11) The prevalence of diabetes among adults increased nearly 60% in the same period, and although women remain more likely to experience diabetes, the prevalence among men has increased more rapidly.(11)

While under- and over-nutrition threaten the health of Sri Lankan adults, a recent review found that the cost of a diet meeting the national FBDG exceeds household food expenditures for more than one third of households.(12) Moreover, Sri Lanka has witnessed an increase in the incidence and intensity of climate shocks in recent decades, including intense droughts, rains, landslides, and floods.(13) In a country where nearly 85% of food is produced domestically, these shocks significantly increase the vulnerability of farmers and consumers to food insecurity.(13,14)

The aim of the present study was to provide evidence about the dietary intake of rural Sri Lankan adults to inform the development of sustainable and cost-effective interventions for improving nutrition and health outcomes via improved diet quality. In particular, we targeted adults engaged in agriculture – the predominant livelihood activity in Sri Lanka – living in districts which are highly vulnerable to climate shocks and food and nutrition insecurity. We sought to identify the specific types of fruits and vegetables already consumed by the study population which could be promoted in future interventions and government programs to improve nutrient intakes. The specific objectives of this analysis were to characterize food group consumption, estimate observed and usual nutrient intakes and the adequacy of micronutrient intakes, and to examine the relative contribution of F&V micronutrient intake.

Methods

This study is a secondary analysis of data from a longitudinal evaluation of the Resilience, Risk Reduction, Recovery, Reconstruction, and Nutrition (R5N) program, which sought to assess impacts of the R5N Food Assistance for Assets nutrition-sensitive agriculture and resilience program, with and without a health promotion component. The evaluation was carried out by [blinded].

Study population. The target population was adults (≥18 years old) living in five rural agricultural districts across Sri Lanka. The program villages were selected due to their vulnerability to environmental shocks and nutrient insecurity. Thirty villages were selected to receive the R5N program by [blinded]. The program evaluation team randomly selected half of the R5N villages to receive the health promotion component, and 15 additional control villages from the same districts based on a community-level matching procedure. The matching variables included demographics, precipitation, temperature, land cover, soil characteristics, proximity to cities, and nighttime light density. Households were eligible for inclusion if at least one adult member of the household had engaged in farming in the past year. In the control group villages, the research team used stratified random sampling to enroll households for which phone numbers could be obtained from electoral lists. The study team sought to enroll all R5N beneficiaries and obtained their phone numbers from [blinded]'s beneficiary list. Additional details regarding the R5N sample selection and methodology are available elsewhere.(15) For the R5N evaluation study, the research team collected data from the primary R5N beneficiary (in the intervention arms) or the household member who was most involved in agriculture (in the control group). If this person was unwilling or unable to participate, another adult member of the household was asked to complete the dietary survey. **Figure 1** illustrates the flow of participants through the study. The final sample size of the baseline dietary survey was 1283 adults. Assuming 30% prevalence of adequate intake (PAI), a sample size of 1283 provides a precision of ±2.5% in estimating the PAI with 95% confidence. If PAI is 50%, our precision is ±2.7%.

Data collection. Baseline data were collected December 2020-February 2021. It included three tablet-assisted phone calls to collect information regarding household characteristics and assets, nutrition knowledge, food security, participation in agriculture, and R5N program exposure. Additional sociodemographic information was collected using a household survey. Variables included sex, age, educational attainment, household income, and household expenditure.

Dietary data were obtained using a 24-hour recall survey conducted via telephone due to the onset of the COVID-19 pandemic and the need to reduce in-person contact. Data were entered into electronic forms in SurveyCTO using tablets.(16) Interviews were conducted using the multiple-pass method, with respondents reporting all foods and beverages consumed on the previous day.(17) Participants reported portion sizes using a pre-determined list of household utensils that are commonly used in Sri Lanka (e.g., tea cups, coconut serving spoons, etc.). Repeat recalls were collected from a random subgroup of the sample on a non-consecutive day. Although information on supplement use was collected, the data was not incorporated into the analysis. Only 4% of respondents reported using a specific micronutrient supplement, and the quantity with which they supplemented was not known.

Data analysis. We used Stata version 17 for data cleaning, management, and descriptive analyses.(18) The wealth index was calculated using principal component analysis of 24 household assets (e.g., material of dwelling floor, access to electricity, television ownership).

To estimate the quantity of each food reported, we applied standardized gram weight conversion factors based on food type and portion unit. When mixed dishes were reported, we disaggregated them using ingredient fractions from a standard recipe database developed by the study team from prior dietary surveys, local informants, and searches of published Sri Lankan recipes. We developed a recipe calculator to estimate the nutritional composition of mixed dishes using ingredient-level nutrient data from the Sri Lankan food composition table (FCT).(19) FCT data was supplemented with values from neighboring countries or the USDA when necessary. The calculator also incorporated nutrient retention factors for cooking and yield factors (to account for water gains or losses) from the United States Department of Agriculture (USDA).(20,21) Each ingredient was assigned a nutrient retention factor based on the assigned food sub-group (e.g., type of meat, type of vegetable, etc.) and primary cooking method of the mixed dish (e.g., boiled, sauteed, fried). The yield factors and ingredient fractions were applied and refined using an iterative process. The [blinded] research team had previously estimated the nutrient values for nearly 400 recipes using the Foodbase 2000 software (Institute of Brain Chemistry, UK). After validating our recipe calculator output against these values, we were able to estimate the yield factors of similar recipes for which we did not have pre-existing nutrient values. The resulting ingredient-level dataset, including foods reported ‘as consumed’ (e.g., fruits, snacks, beverages), served as the basis for the food group analysis.

We assessed consumption of individual foods/ingredients using two levels of food group classification and one additional classification of only F&V groups. The broadest level included 14 food groups which were modified from the Food and Agriculture Organization individual dietary diversity score (IDDS; **Table 1**).(22) In comparison to the IDDS, the present analysis combined meat and eggs due to the low frequency and quantity of consumption in our study population. In contrast, pulses were separated from nuts and seeds since the local diet includes regular consumption of pulses. The remaining reported food items fell into three distinct categories (beverages, coconut milk, and spices/seasonings) and were categorized as such, rather than 'miscellaneous' as used in the IDDS, due to the important contribution of coconut milk and seasonings to micronutrient intake in our study population. In this analysis, we sought to gain a deeper understanding of the contribution of F&V to nutrient adequacy, and therefore used a further classification of 25 food groups which disaggregated F&V (**Table 1**). Categorization was based on standard food groups and nutrient profile. The food groups were refined during data analysis to include only categories which contributed ≥2%, on average, to total intake of one or more micronutrients. For the final analysis, we assessed the proportional contribution of each reported F&V to the total pool of micronutrients obtained only from F&V. As above, we refined the categories during analysis and reported those which contributed ≥2% of one or more micronutrients. Based on this approach, we retained 16 unique F&V and 7 F&V groups (**Table 1**). We performed descriptive statistics characterizing the quantities of foods consumed and the contribution of each food group to total nutrient intake in Stata.(19) A serving of F&V was defined as 80 g.(23) We used ANOVA tests and Jonckheere–Terpstra tests for trend to assess whether the proportion of energy derived from each food group differed by demographic subgroup (sex, district, and wealth quintile).

We estimated the usual intake distributions of macro- and micronutrients using the National Cancer Institute (NCI) method in SAS version 9.4.(24,25) We also estimated the PAI for 11 micronutrients (iron [expressed in mg], calcium [mg], zinc [mg], thiamine [mg], niacin [mg], riboflavin [mg], folate [µg dietary folate equivalents; DFE], vitamin A [µg of retinol equivalents; RE], vitamin C [mg], vitamin B6 [mg], and vitamin B12 [µg]). Vitamin A was expressed in REs to align with The European Food Safety Authority's population reference intake and the harmonized average nutrient requirements (H-ARs).(26,27) To estimate 95% CIs, we used bootstrap resampling and calculated standard errors from the bootstrapped estimates. PAI was calculated as the proportion of the study sample whose intake exceeded the age- and sex-specific H-ARs, which were developed for applicability at the global level.(27) For iron and zinc, we selected the requirements associated with moderate absorption and semi-unrefined diets, respectively. For iron, the H-AR assumes 10% absorption due to moderate phytate intake and some consumption of meat and fish. Similarly for zinc, the increased requirement accounts for moderate phytate intake (assuming 900 mg/person/day).(27) Nine micronutrients (calcium, zinc, vitamin A, thiamine, riboflavin, niacin, vitamin B6, folate, and vitamin C) were analyzed using the Simulating Intake of Micronutrients for Policy Learning and Engagement (SIMPLE) SAS macro, which reduces the processing time required to run the NCI method.(28) Vitamin B12 was consumed episodically, i.e., >10% of the study sample did not consume it on the recall day. Therefore, we used the two-part NCI model to estimate the probability of consumption and the consumption-day amount.(29) Finally, to assess the PAI of iron, we used the SIMPLE-Iron SAS macro, assuming a mixture of oral contraceptive users and non-users in the population.(30) The analysis of iron is unique since the distribution of requirements for menstruating women does not satisfy the assumption that nutrient requirements are symmetrical and thus requires use of the full-probability method of analysis.(30) All PAIs were analyzed by sex, wealth quintile, and district. We used t-tests to assess whether differences in the PAI of micronutrients differed by demographic subgroup. Batticaloa and wealth quintile1 were used as the reference groups for hypothesis testing between districts and wealth quintile, respectively.

Results

The study sample included 1283 individuals, with repeated 24-hour recalls from 769 participants (60%) collected 3-10 days after the initial interview. Approximately one third of respondents were female (n=486), and the median age was 44 years, ranging from 18 to 88 (**Table 2**). Enrollment by district as a percentage of the total sample ranged from 13% in Mannar in the north to 25% in Monaragala in the south.

Food group consumption. Average daily reported energy intake was 1922±836 kcal (**Figure 2**). More than half of energy came from grains, including baked goods and snacks (56%). Coconut milk contributed 12% of reported energy, followed by sweets and added sugars (6%). Together, these food groups accounted for nearly three quarters of the average diet. White rice alone (including parboiled, polished, and flour varieties), supplied 29% of energy intake, while F&V contributed just 4% of energy, on average.

As a proportion of total energy, male and female food group consumption was similar (**Figure 2**). Three food groups were significantly different by sex: meat and eggs (2.2±5.0% of kcal among men vs. 1.5±3.4% among women, p<0.01), sweets (5.4±6.0% vs. 6.1±6.7%, respectively, p=0.04), and spices/seasonings (0.8±0.5% vs. 0.9±0.7%, respectively, p=0.01).

There was no difference in the proportion of energy from pulses, seafood, beverages, or spices/seasonings by geographic region (p>0.05). All other food group differences were statistically significant (p<0.01). Participants in Matale and Monaragala, the central and southernmost study sites, respectively, reported higher proportions of energy from grains, fruits, and vegetables, and lower proportions of energy from sweets, dairy, and coconut milk relative to participants in the other three districts. Participants in Mannar and Mullaitivu, the northernmost study districts, reported the highest consumption of sweets, oils/fats, meat/eggs, and dairy and the lowest proportion of energy from grains.

Differences in the proportion of energy from grains, coconut milk, fruits, vegetables, and dairy were statistically significant between wealth quintiles. As wealth quintile increased, the proportional consumption of grains and vegetables decreased, and consumption of coconut milk and dairy increased (p<0.01). Although the test for trend in fruit consumption was not statistically significant across wealth quintiles (p=0.1), the percent of energy derived from fruit was nearly twice as high among participants in the lowest two quintiles compared to those in the highest three quintiles, on average (2.4±5.7% vs. 1.3±3.0% g, p<0.01). Similarly, the test for trend was not significant for meat and egg consumption, but participants in the highest three wealth quintiles derived a higher proportion of energy from meat and eggs than those in the lowest two wealth quintiles (2.2±4.8% vs. 1.6±3.8%, p=0.02).

***Usual nutrient intake and prevalence of adequate micronutrient intake*.** The estimated usual energy intake in the study sample was 1836±22 kcal (**Table 2)**. Usual protein, fat, and carbohydrate intake was 53±1, 56±1, and 292±3 g, respectively. Of the total kilocalories consumed, 11±10% was derived from protein, 26±9% from fat and 62±10% from carbohydrates (alcohol contributed an additional <1±4%).

The PAI was low for most of the micronutrients examined in this analysis (**Table 3**). PAI was highest for thiamine (68%) and riboflavin (64%). High thiamine intake was largely due to parboiled rice (22% of total intake), while parboiled and red rice, milk powder, and brewed black tea contributed the largest proportions of riboflavin (5-9% each). PAI was modest for iron (34%) and vitamin A RE (33%). For all other nutrients, PAI was below 25%. Dietary intakes of calcium, vitamin C, and zinc were the most problematic, with 3%, 8%, and 8% of the sample consuming adequate amounts, respectively.

The prevalence of adequate iron, zinc, and niacin intakes were statistically significantly different between men and women: 30% of women consumed adequate iron vs. 37% of men (p<0.01), 14% of women consumed adequate zinc vs. 5% of men (p<0.01), and 22% of women consumed adequate niacin vs. 16% of men (p<0.01) (**Figure 3**). There was little variation in PAI among the sampled districts or wealth quintiles. Vitamin B12 was the only nutrient for which PAI was statistically significantly different across districts and wealth quintiles. It ranged from 16% adequate in Batticaloa to 9% in Mullaitivu (p=0.03), and it was negatively correlated with wealth quintile, ranging from 20% among the wealthiest participants to 6% among the poorest (p<0.01).

Average contribution of food groups to micronutrient intake. Refined grains, including baked goods and snacks, provided the largest proportions of calcium, iron, zinc, thiamine, riboflavin, niacin, vitamin B6, and folate (19-55% of reported intake per person) due to the large quantities consumed (**Figure 4**).

The study population consumed a variety of more nutrient-dense foods, including fish/shellfish, dairy, pulses, and capsicum/chilies. Fish and shellfish contributed nearly two thirds of the sample's vitamin B12 intake, and 11-16% of calcium, vitamin B6, and folate (**Figure 4**). Capsicums/chilies were the largest contributor of vitamin C (26%) and the third largest source of vitamin A RE (14%). Spices/seasonings (primarily curry leaves) and dark leafy greens supplied the highest proportions of vitamin A RE (23% and 21%, respectively). Other notable sources of micronutrients include dairy (the second greatest source of vitamin B12 and calcium), pulses (the third highest contributor of iron and thiamine), and coconut milk (the second largest source of iron).

Relative contribution of individual F&V to total micronutrient intake from all F&V. Reported consumption of fruit was 71±243 g, or 0.9±3.0 servings per day, and vegetables was 118±117 g, or 1.5±1.5 servings per day. Out of the nutrients that participants obtained from F&V, mango accounted for the highest proportions of vitamin C, folate, vitamin A RE, and vitamin B6 (18-39%) intake; the second highest proportions of thiamine and riboflavin intake; and the third highest proportions of iron and calcium (8-16%) (**Supplemental Figure 1**). Capsicum and chilies supplied the largest proportions of thiamine, riboflavin, and niacin, and the second largest proportions of F&V-specific intake of vitamin C, iron, and vitamin B6. Bananas were the most significant F&V source of zinc and iron (30% and 15%, respectively), while green/winged beans and curry leaves provided the greatest proportion of niacin and calcium from F&V, respectively (26% and 13%).

Discussion

On average, respondents derived 56% of their total energy from grains, more than half of which was from white rice. Despite being a relatively poor source of micronutrients, refined grains provided the largest proportions of 8 key micronutrients due to the large quantities consumed. Of the 11 micronutrients assessed, the PAI for 7 nutrients was less than 25%. Approximately one third of the study sample reported adequate intake of iron and vitamin A. PAI was highest for riboflavin and thiamine (approximately 65%), reflecting overall low micronutrient intake. The average consumption of F&V in our sample was approximately 189 g, or 2.4±3.5 servings, per day. Out of the nutrients that participants obtained from F&V, mango, capsicum/chilies, bananas, green/winged beans, and curry leaves were the most significant sources of micronutrients.

The Sri Lankan FBDG recommend that adults consume at least 400 g/day of F&V (3-5 servings of vegetables and 2-3 servings of fruit).(2) In the present study, participants consumed less than half of the minimum recommendation. A nationally representative survey conducted in Sri Lanka in 2021 reported F&V consumption of 4.6 servings per day among adults (1.2 and 3.3 servings of F&V, respectively), which is nearly double the amount reported in our study population.(5) One might expect that the higher intake of F&V in the national sample is due to the inclusion of individuals with higher income; however, we found lower F&V consumption among the highest wealth quintiles in our sample. COVID-19 likely affected consumption of F&V and ASF among our sample. Throughout 2020, Sri Lankan consumers were affected by market closures, significant disruptions in the local supply chain, loss of livelihoods, and reduced access to animal feed.(31) Although the government distributed seed packets and promoted home gardens nationwide, the uptake and establishment of the national home gardening program is not well understood. Moreover, newly established crops or gardens may not have yielded edible F&V for several months after distribution. Differing data collection methods likely also played a role. The national survey used a food frequency questionnaire (FFQ) to estimate the average numbers of servings consumed per day from self-reported consumption days per week and the number of servings per consumption-day.(5) Furthermore, the F&V serving sizes were depicted on cards shown to the participant, which do not necessarily align with the 80 g/serving conversion used in the present analysis.

In an earlier nationally representative survey in Sri Lanka, which collected data in 2011 using 24-hour recalls, adults reported consuming 2.2 servings/day of F&V.(4) The slightly lower consumption of F&V reported by Jayawardena et al. relative to our findings is consistent with the trend of increasing F&V consumption over time seen in the recurring STEPwise approach to NCD risk factor surveillance (STEPS) surveys in Sri Lanka.(5) In the 2006 STEPS survey, respondents reported consuming 3.2 servings/day of F&V, which increased to 4.3 servings/day in the 2015 survey, and 4.6 in the aforementioned 2021 survey. Additionally, the 2011 survey by

Jayawardena et al. reported that males consumed more F&V than females (2.4 vs. 2.0 servings/day).(4) This may explain the higher intake in our study, given the overrepresentation of males.

While the contribution of total energy from protein in our study sample was similar to a nationally representative study conducted in Sri Lanka in 2014, the contribution from fat and carbohydrates diverged.(32) In our sample, 26% of energy came from fat and 62% from carbohydrates, vs. 19% and 71%, respectively, in the study conducted by Jayawardena, et al.(32) These differences may be partially due to the use of in-person recalls and portion size estimation aids in the 2014 study. Moreover, the data reported by Jayawardena et al. were collected ten years prior to the data presented in the current analysis. Due to significant evolution of the political landscape and increased income levels in Sri Lanka in the past half century, food consumption patterns have shifted noticeably.(10,33) The nutrition transition may have contributed to the higher proportion of fat in our sample. In the present study, biscuits contributed the largest proportion of fat intake (>7%) after coconut milk, which illustrates a shift towards ultra-processed packaged foods. The findings from a more recent national survey, which collected data in late 2021, were consistent with our results. The mean energy intake in the survey by Jayatissa et al. was 1902 kilocalories, 63% of which came from carbohydrates, 22% from fat and 12% from protein.(34) Participants in their study reported slightly higher mean energy and macronutrient intakes, which may be due to the inclusion of respondents in urban areas and/or with a higher socioeconomic status, sampling respondents several months after the largest waves of COVID-19 had passed, and the collection of data at the household level (from which individual-level intake was estimated using consumption units).(35)

A 2020 USDA commodity report stated that annual per capita rice consumption in Sri Lanka was 107 kg, which amounts to 293 g/day.(36) This figure is relatively consistent with our findings, in which respondents consumed 235 g/day of rice (all varieties combined). The overestimation by the USDA may be explained by the use of Household Consumption and Expenditure Survey data, which does not account for spoilage or food waste at the household level.(37) The participants in our study reported approximately 13 servings/day of grains and starchy staples, which is the maximum recommended by the national FBDG (8-13 servings).(2) Although the guidelines recommend that grains be primarily whole or unrefined, nearly all of the grains and starchy staples reported by our respondents were refined. A recent literature review found that red rice and other traditional varieties are re-gaining popularity in Sri Lanka, but supply has not yet caught up with increasing demand, leading to high retail prices and limited affordability for consumers.(10)

Coconut milk was the second largest source of energy and the largest source of fat in our sample, which aligns with findings from a recent FBDG technical review.(38) In the present study, participants reported 103 g of coconut milk/day – slightly higher than the 90 g/day estimated in a 2019 24-hour recall survey among Sri Lankan women.(38) Again, the difference is likely due to the inclusion of men in our study, who reported >30% higher energy intake than women and the same proportion of energy from coconut milk.

Study participants living in Matale and Monaragala reported the lowest proportions of energy intake from dairy, coconut milk, and sweets, and the highest proportions of energy from grains, fruits, and vegetables. These districts are predominantly Sinhala, whose traditional diet is largely comprised of rice with small portions of 1-2 vegetables. In Mannar and Mullaitivu, participants reported the highest consumption of meat, eggs, and dairy, which could be partly due to traditional dietary customs typical for those districts. Wealth distribution within the study sample likely also accounts for some of the differences in food group consumption, as participants living in Matale and Monaragala were more likely to be in the lowest two wealth quintiles compared to respondents in the other three study areas. The trends we observed with respect to wealth quintile (i.e., a positive correlation with ASF and negative correlation with grains, fruit, and vegetables) are consistent with the global nutrition transition.(33)

The aforementioned 2019 survey of Sri Lankan women reported that cereals, green leafy vegetables, and pulses were the top three contributors to iron intake, and the top four contributors to vitamin A intake were vegetables, fruits, egg, and dairy.(38) In our study sample, cereals were also the largest contributor to iron intake, followed by coconut milk and pulses. Our results for vitamin A were also similar: vegetables were the primary contributor, followed by spices/seasonings (i.e., curry leaves), dairy, fruit, and eggs. In terms of specific F&V, both studies found mango to be the leading source of vitamin A.

Among our study participants, seafood was an important contributor of vitamin B6, vitamin B12, calcium, and folate. Per capita consumption was 32 g/day, which is on par with the national average of 37 g/person/day estimated in 2021 by the Sri Lankan Ministry of Fisheries.(39) Despite the contribution of seafood to micronutrient adequacy in our study sample, overall intake of the micronutrients that seafood can provide was concerningly low (i.e., zinc, iron, and calcium). To some extent, this may be related to the decline in fish production in Sri Lanka in recent years as a result of the pandemic and economic crisis which lead to fuel shortages.(40) In addition to seafood, increasing consumption of pulses, dairy, and eggs – foods which are already consumed in modest quantities in the study population – could help close some of the gaps between reported and recommended micronutrient intakes.

For men and women, the usual intake of carbohydrates in our sample was 292 g, and the usual protein intake was 53 g. Carbohydrate consumption was more than double the 130 g recommended daily allowance (RDA) for adults, and although protein intake was sufficient for women (RDA = 46 g), it was below the 56 g RDA for men.(30) To our knowledge, no studies have published estimates using statistically modeled usual micronutrient intakes or the PAI based on usual intake among Sri Lankan adults. A recent nationally representative study in Sri Lanka assessed micronutrient intake by estimating intake from household-level consumption data.(34) The median reported intakes for calcium, iron, niacin, and vitamin B6 were similar to our findings (±15%); however, they found significantly lower intakes of vitamin A, thiamine, riboflavin, folate, and vitamin C, and significantly higher median intakes for zinc and vitamin B12. Concordantly, the PAI for zinc and vitamin B12 estimated by Jayatissa et al. was considerably higher than the PAI in our sample. The divergence in results may be due to differing analytical approaches. Because of the high degree of within-person variation in dietary intake, the removal of this variation through measurement error modeling is important for obtaining unbiased estimates of the PAI.(24) Moreover, the higher observed intake of zinc and vitamin B12 in the nationally representative sample may be due to the inclusion of urban populations who have higher incomes, on average, and therefore consume larger quantities of animal-source foods.

Recent studies in Cambodia and South India estimated PAI using similar statistical methods to ours, and their findings suggest that some variation in micronutrient intake exists among different adult population groups in South Asia.(41,42) Of the six micronutrients assessed in the Cambodia analysis, the PAI for four nutrients was within 10% of our results (calcium, zinc, vitamin A, and riboflavin). They found a higher PAI for iron (50% compared to 34% among our sample), and a lower PAI for thiamine (46% vs. 68%, respectively).(41) The higher overall consumption of food, and thus micronutrients, among men in our study may explain some of the incongruity, since the study in Cambodia was conducted only among rural-dwelling women.

Among the sample in India, PAI was again similar for zinc and vitamin A, in addition to vitamin B12, and the PAI for iron was substantially higher (89%).(42) The PAI for thiamine was similar, but still lower by 10% (58% in India versus 68% in our sample). In contrast, the study in India found substantially higher PAI for calcium, niacin, and vitamin C, and lower PAI for riboflavin and folate. Of note, the analysis by Shalini et al. averaged three 24-hour recalls to estimate usual nutrient intake before calculating the probability of adequacy relative to requirements. As noted previously, not accounting for within-person variation may have biased their estimates.(24) Nevertheless, the differences in PAI appears to be at least partially explained by actual differences in food consumption. For example, Shalini et al. found that milk/ milk products contributed 60% of calcium in their sample compared to 13% in rural Sri Lanka. Similarly, fruit, green leafy vegetables, and pulses contributed a substantially larger proportion of vitamin C, iron, and folate among South Indian respondents compared to our respondents.(42)

In the demographic subgroup comparison of PAI, we found statistically significant differences between men and women for iron, zinc, and niacin. It is worth noting, however, that the estimated usual intakes of these nutrients were the same for men and women, and that the difference in PAI was a result of different H-ARs between the sexes. We also found a statistically significant correlation between the PAI of vitamin B12 and wealth quintile, which is consistent with our findings that dairy, meat, and egg consumption increased with wealth quintile. In LMICs, these food groups are relatively expensive compared to starchy staples.(43) Although, in one study fish was the most expensive food group per 1000 kcal, it is also the most important source of B12 in our study population, and we found no difference in the proportion of energy from seafood by wealth quintile.(43) This suggests that promoting increased fish intake in the study population could be an equitable way to achieve adequate B12 intake in the study population.

There are several limitations to consider in the present analysis. Recall bias is an inherent source of error in retrospective self-reported data collection. However, this bias tends to be lower for 24-hr recall, since it only requires the participant to recount intake from the previous day, while other types of dietary data collection methods (e.g., FFQs) use a longer recall period.(44) The onset of the COVID-19 pandemic and necessity of conducting interviews via telephone instead of in-person may have decreased the precision of portion size estimations because food models and portion size tools could not be shown during the interview. Participants were asked to report portion sizes using household utensils and dishware that are common in Sri Lanka, although those same utensils may not have been present in every respondent’s home. During the protocol modifications, the study team dedicated significant effort into developing the list of possible portion sizes for each food item to reduce reporting error. Few studies have compared the validity of phone-based 24-hour recalls relative to those collected in-person. The only study to our knowledge which included a gold standard reference value reported that both recall methods underestimated true energy intake, but the phone and in-person estimates were not different from each other.(45) Similarly, in a larger sample size which included men and women, the researchers found no difference in energy or protein intake between phone and in-person interviews.(46) Given the uncertainty around the performance of phone-based 24-hour recalls, we developed a follow-up study to validate phone and in-person recalls against weighted food records. Preliminary results show that, within our study population, phone recalls performed as well as those conducted face-to-face across several metrics.(47) Therefore, we expect that the use of phone-based interviews did not have a significant impact on the validity of our findings.

The use of telephone-based interviews may have introduced selection bias. Given the ubiquity of telephone subscriptions in Sri Lanka, it is unlikely that the use of phone surveys had a significant impact on the generalizability of our findings.(48) There is some evidence from another rural district in Sri Lanka that among a subset of adult women, more than 98% had at least one mobile phone in the household.(49) In fact, the use of phone surveys may have decreased selection bias since we were able to survey participants who work long hours outside the home and may not have been available for in-person surveys. Nevertheless, the present study is not regionally or nationally representative. The objective of the study was to assess the food and nutrient intake of a population that is particularly vulnerable to climate shocks and – consequently – food and nutrient insecurity. As a result, we cannot necessarily extrapolate these results to all rural-dwelling adults in Sri Lanka.

Finally, we recognize that the findings from our study may not reflect typical nutrient intakes in Sri Lanka due to COVID-19, political and economic turmoil in the country, and increasing frequency of climate shocks. In particular, the pandemic affected global supply chains and availability of some food commodities, as well as national revenue from tourism, which may have affected consumption patterns during the data collection period. However, the R5N study collected data at four timepoints throughout 2021-2024, which will provide additional data on food group consumption and micronutrient intake in the same population after the country had recovered from COVID-19 and the economic crisis. The follow-up data will enable us to assess the extent to which these external factors may have played a role in changing food patterns in Sri Lanka.

Strengths of our study include rigorous enumerator training, a large sample size, quantitative dietary intake estimates, the compilation of a recipe database and dietary reference tables specific to Sri Lanka, and comprehensive data cleaning activities. One of the most important elements of our study was the collection of repeat recalls from more than half of respondents and use of the NCI method for usual nutrient intake estimation, which account for intra-individual variation in food consumption.

Conclusions

The goal of our analysis was to assess food group consumption, nutrient intakes, adequacy of micronutrient intakes relative to requirements, and the contribution of specific F&V to micronutrient intake. Our findings are consistent with previous studies that have observed dietary quality and diversity in LMICs well below what is recommended for optimal health. Estimated usual intakes of calcium, zinc, vitamin C, vitamin B12, and niacin were particularly low in our study population. The micronutrient gaps are driven by high consumption of rice and low consumption of F&V and ASF.

F&V are a critical source of fiber, micronutrients, and phytonutrients in the diet, and inadequate consumption has adverse consequences on one's risk of cardiovascular disease, cancer, and all-cause mortality.(1) A 2015 survey estimated that >90% of Sri Lankan adults have at least one risk factor for non-communicable diseases (NCD), and that >70% of the disease burden in the country is due to NCDs.(5) Improving consumption of these food groups is imperative to improving health outcomes in the country. Cost, availability, personal preferences, social and cultural norms, workload and time pressures, and environmental factors have been reported as significant barriers to adequate F&V consumption in LMICs.(50)

More research is needed to identify and evaluate solutions to increasing intake of micronutrient-rich foods such as F&V and ASF in the study population. For example, nutrition-sensitive agricultural interventions may be used to introduce more drought-resilient, nutrient dense crop varieties or to diversify livelihoods. The agricultural sector in Sri Lanka may also benefit from the introduction of technologies to reduce reliance on manual labor, and to better predict forthcoming climate shocks. While this survey provides useful insight into the nutrient intakes of a nutritionally vulnerable population, we recommend a future assessment of usual nutrient intakes among a nationally representative sample adults in Sri Lanka. While increasing F&V consumption would close some micronutrient gaps in the population in a way that is environmentally sustainable and affordable for consumers, improving accessibility of ASF and/or food fortification will likely also be needed to effectively increase the PAI of certain micronutrients (e.g., calcium and zinc).

References

1. Aune D, Giovannucci E, Boffetta P, et al. Fruit and vegetable intake and the risk of cardiovascular disease, total cancer and all-cause mortality-a systematic review and dose-response meta-analysis of prospective studies. Int J Epidemiol. 2017 Jun 1;46(3):1029–56.

2. Food Based Dietary Guidelines for Sri Lankans: Practitioner's Handbook. Sri Jayawardenepura Kotte: Ministry of Health, Nutrition Division; 2021. Report No.: 3rd Edition.

3. Weerasekara PC, Withanachchi CR, Ginigaddara GAS, et al. Understanding Dietary Diversity, Dietary Practices and Changes in Food Patterns in Marginalised Societies in Sri Lanka. Foods. 2020 Nov 13;9(11):E1659.

4. Jayawardena R, Byrne NM, Soares MJ, et al. Food consumption of Sri Lankan adults: an appraisal of serving characteristics. Public Health Nutr. 2013 Apr;16(4):653–8.

5. STEPwise approach to NCD risk factor surveillance (STEPS): Sri Lanka [Internet]. World Health Organization (WHO); 2024 [cited 2023 Mar 30]. Available from: https://www.who.int/teams/noncommunicable-diseases/surveillance/data/sri-lanka

6. Abeywickrema S, Gunathunga S, Walpita JK, et al. Evaluating sensory impacts of sustained Plant-Based Diets: Altered sensitivity and hedonic responses to Meat-Related odours in Sri Lankan young adults. Food Quality and Preference. 2024;117:105151. doi:10.1016/j.foodqual.2024.105151

7. Mark HE, Houghton LA, Gibson RS, et al. Estimating dietary micronutrient supply and the prevalence of inadequate intakes from national Food Balance Sheets in the South Asia region. Asia Pac J Clin Nutr. 2016;25(2):368-376. doi:10.6133/apjcn.2016.25.2.119

8. Jayatissa R, Perera A, Alwis N. National Nutrition and Micronutrient Survey in Sri Lanka: 2022. Department of Nutrition, Medical Research Institute in partnership with UNICEF and WFP; 2023.

9. Seferidi P, Hone T, Duran AC, et al. Global inequalities in the double burden of malnutrition and associations with globalisation: a multilevel analysis of Demographic and Health Surveys from 55 low-income and middle-income countries, 1992–2018. The Lancet Global Health. 2022 Apr 1;10(4):e482–90.

10. Bandara S, Kumara T, Dharmadasa S, et al. Changes in Food Consumption Patterns in Sri Lanka: Food Security and Sustainability: A Review of Literature. Open Journal of Social Sciences. 2021 Sep 29;9(10):213–37.

11. Global Nutrition Report [Internet]. 2022 [cited 2022 Oct 10]. Country Nutrition Profiles: Sri Lanka. Available from: https://globalnutritionreport.org/resources/nutrition-profiles/asia/southern-asia/sri-lanka/

12. Dizon F, Herforth A, Wang Z. The cost of a nutritious diet in Afghanistan, Bangladesh, Pakistan, and Sri Lanka. Global Food Security. 2019 Jun 1;21:38–51.

13. Gunaratne MS, Radin Firdaus RB, Rathnasooriya SI. Climate change and food security in Sri Lanka: towards food sovereignty. Humanit Soc Sci Commun. 2021 Oct 12;8(1):1–14.

14. Climate change, food security and rural livelihoods in Sri Lanka. Colombo, Sri Lanka: Institute of Policy Studies; 2018.

15. Singh N, Scott S, Kumar N, et al. Food Insecurity and Perceived Effects of COVID-19 on Livelihoods in Rural Sri Lanka. Food Nutr Bull. 2023 Dec;44(4):229–39.

16. SurveyCTO [Internet]. Massachusetts, USA: Dobility, Inc.; 2019. Available from: https://www.surveycto.com

17. Gibson R, Ferguson E. An interactive 24-Hour recall for assessing the adequacy of iron and zinc intakes in developing countries. Washington D.C.: ILSI Press; 1999.

18. Stata Statistical Software: Release 17. College Station, TX: StataCorp LLC; 2021.

19. Jayatissa R, Perera AG, G. Silva AB, et al. Sri Lanka Food Composition Tables. Medical Research Institute of Sri Lanka; 2021 Oct.

20. USDA Table of Nutrient Retention Factors: Release 6 [Internet]. Maryland, USA: U.S. Department of Agriculture (USDA); 2007 Dec. Available from: https://www.ars.usda.gov/arsuserfiles/80400530/pdf/retn06.pdf

21. Food yields summarized by different methods of preparation [Internet]. Washington, D.C.: U.S. Department of Agriculture (USDA); 1975 Sep. Available from: https://www.ars.usda.gov/ARSUserFiles/80400530/pdf/ah102.pdf

22. Kennedy G, Ballard T, Dop M. Guidelines for Measuring Household and Individual Dietary Diversity [Internet]. Rome: Food and Agriculture Organization of the United Nations (FAO); 2010 [cited 2023 Mar 31]. Available from: https://www.fao.org/3/i1983e/i1983e.pdf

23. WHO STEPS Surveillance Manual [Internet]. Geneva, Switzerland: World Health Organization (WHO); 2017 Jan [cited 2024 Mar 29]. Available from: https://www.who.int/docs/default-source/ncds/ncd-surveillance/steps/steps-manual.pdf

24. Tooze JA, Kipnis V, Buckman DW, et al. A mixed-effects model approach for estimating the distribution of usual intake of nutrients: The NCI method. Stat Med. 2010 Nov 30;29(27):10.1002/sim.4063.

25. SAS Institute Inc. Cary, N.C.: SAS Institute Inc.; 2023.

26. EFSA Panel on Dietetic Products, Nutrition, and Allergies (NDA). Scientific Opinion on Dietary Reference Values for vitamin A. *EFSA Journal*. 2015;13(3):4028. doi:10.2903/j.efsa.2015.4028

27. Allen LH, Carriquiry AL, Murphy SP. Perspective: Proposed Harmonized Nutrient Reference Values for Populations. Adv Nutr. 2020 May 1;11(3):469–83.

28. Luo H, Dodd KW, Arnold CD, et al. Introduction to the SIMPLE Macro, a Tool to Increase the Accessibility of 24-Hour Dietary Recall Analysis and Modeling. J Nutr. 2021 Mar 9;151(5):1329–40.

29. Tooze JA, Midthune D, Dodd KW, et al. A new statistical method for estimating the usual intake of episodically consumed foods with application to their distribution. J Am Diet Assoc. 2006 Oct;106(10):1575–87.

30. Institute of Medicine (US) Standing Committee on the Scientific Evaluation of Dietary Reference Intakes. DRI Dietary Reference Intakes: Applications in Dietary Assessment [Internet]. Washington (DC): National Academies Press (US); 2000 [cited 2022 Jul 19]. 73–105 p. Available from: https://ods.od.nih.gov/HealthInformation/nutrientrecommendations.aspx

31. van Buitenlandse ZM. Impact of COVID19 on food supply chains in Sri Lanka. Agricultural News Abroad. May 27, 2020. Accessed September 9, 2024. https://www.agroberichtenbuitenland.nl/actueel/nieuws/2020/05/27/impact-of-covid19-on-food-supply-chains-in-sri-lanka

32. Jayawardena R, Thennakoon S, Byrne N, et al. Energy and nutrient intakes among Sri Lankan adults. Int Arch Med. 2014 Jul 11;7:34.

33. Weerahewa J, Sewwandi Wijetunga C, Chandra Babu S, et al. Food Policies and Nutrition Transition in Sri Lanka: Historical Trends, Political Regimes, and Options for Interventions. Washington, D.C.: International Food Policy Research Institute; 2018 May.

34. Jayatissa R, Jayawardana R, Perera AG, et al. Nutritional status and dietary intake of the population aged 1-60 years during the COVID-19 Pandemic in Sri Lanka. The Ceylon medical journal. 2023 Aug 24;68:9–20.

35. Wickramasinghe D, Fernando VK. Sri Lanka’s fight against COVID-19: a brief overview. Pandemic Risk, Response, and Resilience. 2022;129–42.

36. Galappattige A. Grain and Feed Annual [Internet]. New Delhi: U.S. Department of Agriculture (USDA); 2020 May. Report No.: CE2020-0005. Available from: https://apps.fas.usda.gov/newgainapi/api/Report/DownloadReportByFileName?fileName=Grain%20and%20Feed%20Annual_New%20Delhi_Sri%20Lanka_03-27-2020

37. Fiedler JL, Lividini K, Bermudez OI, et al. Household Consumption and Expenditures Surveys (HCES): a primer for food and nutrition analysts in low- and middle-income countries. Food Nutr Bull. 2012 Sep;33(3 Suppl):S170-184.

38. Technical Review Report: 2019-2020 Sri Lankan Food Based Dietary Guide Lines Evidence Review [Internet]. Sri Lanka: Ministry of Health, Nutrition and Indigenous Medicine (MoH) Sri Lanka; 2021 [cited 2024 Apr 3]. Available from: https://nutrition.health.gov.lk/wp-content/uploads/2021/10/Tec-Report-Final-draft.pdf

39. Annual Performance Report for the year 2021 [Internet]. Colombo, Sri Lanka: State Ministry of Ornamental Fish, Inland Fish & Prawn Farming, Fishery Harbour Development, Multiday Fishing Activities and Fish Exports; 2021 [cited 2024 Apr 3]. Report No.: 405. Available from: https://www.parliament.lk/uploads/documents/paperspresented/1657004026002914.pdf

40. *Sri Lanka Fisheries Industry Outlook 2022*. National Aquatic Resources Research and Development Agency (NARA); 2023. http://www.nara.ac.lk/wp-content/uploads/2023/10/Fisheries-Industry-Outlook-2022.pdf

41. Verbowski V, Talukder Z, Hou K, et al. Effect of enhanced homestead food production and aquaculture on dietary intakes of women and children in rural Cambodia: A cluster randomized controlled trial. Matern Child Nutr. 2018 Jul;14(3):e12581.

42. Shalini T, Sivaprasad M, Balakrishna N, et al. Micronutrient intakes and status assessed by probability approach among the urban adult population of Hyderabad city in South India. Eur J Nutr. 2019 Dec;58(8):3147–59.

43. Bai Y, Alemu R, Block SA, et al. Cost and affordability of nutritious diets at retail prices: Evidence from 177 countries. Food Policy. 2021 Feb;99:101983.

44. International Dietary Data Expansion Project [Internet]. [cited 2023 Jun 10]. 24-hour Dietary Recall (24HR). Available from: https://inddex.nutrition.tufts.edu/data4diets/data-source/24-hour-dietary-recall-24hr

45. Tran KM, Johnson RK, Soultanakis RP, et al. In-person vs telephone-administered multiple-pass 24-hour recalls in women: validation with doubly labeled water. J Am Diet Assoc. 2000;100(7):777-783. doi:10.1016/S0002-8223(00)00227-3

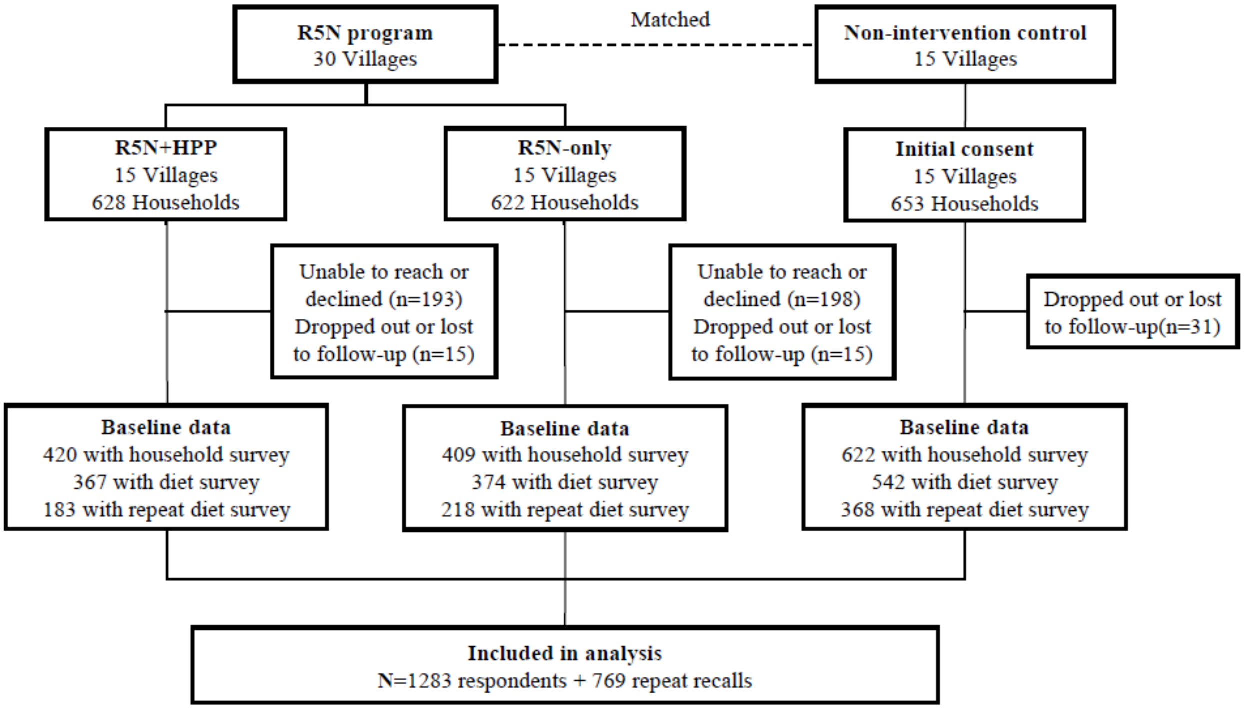
46. Bogle M, Stuff J, Davis L, et al. Validity of a telephone-administered 24-hour dietary recall in telephone and non-telephone households in the rural Lower Mississippi Delta region. *J Am Diet Assoc*. 2001;101(2):216-222. doi:10.1016/S0002-8223(01)00056-6

47. Joyce CA, Gelli A, Arnold CD, et al. Relative validity of interviewer-administered 24-hour recalls collected by phone and in-person versus weighed food records in rural Sri Lanka (unpublished). In: Annual Agriculture, Nutrition and Health (ANH) Academy Week. ANH Academy; 2025.

48. World Bank Open Data [Internet]. 2023 [cited 2023 May 24]. Mobile cellular subscriptions (per 100 people) - Sri Lanka. Available from: https://data.worldbank.org

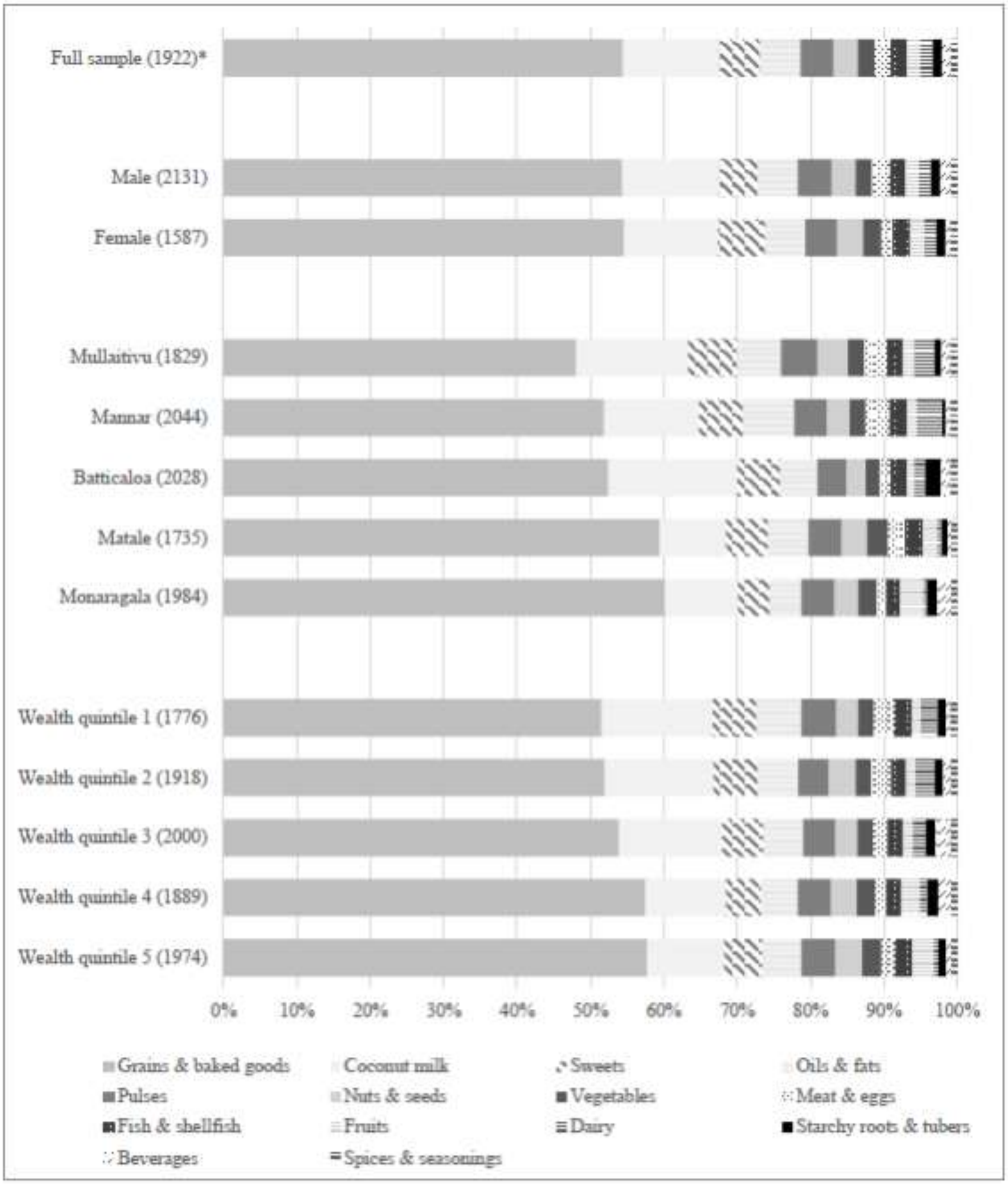
49. Jayasinghe I, Wickramasinghe Y, Kurera DM, et al. Feasibility of using telephone interviews and internet-based message services during the COVID-19 pandemic in rural Sri Lanka: experiences of the Rajarata Pregnancy Cohort. *Rural Remote Health*. 2022;22(2):7442. doi:10.22605/RRH7442

50. Kehoe SH, Dhurde V, Bhaise S, et al. Barriers and Facilitators to Fruit and Vegetable Consumption Among Rural Indian Women of Reproductive Age. Food Nutr Bull. 2019 Mar;40(1):87–98.



R5N, Resilience, Risk Reduction, Recovery, Reconstruction, and Nutrition; HPP, health promotion process

Figure 1. CONSORT flow diagram of participants through the R5N evaluation study



*Average reported kilocalories by subgroup

Figure 2. Average daily contribution of 14 food groups to total energy intake among rural Sri Lankan adults (%, N=1283)

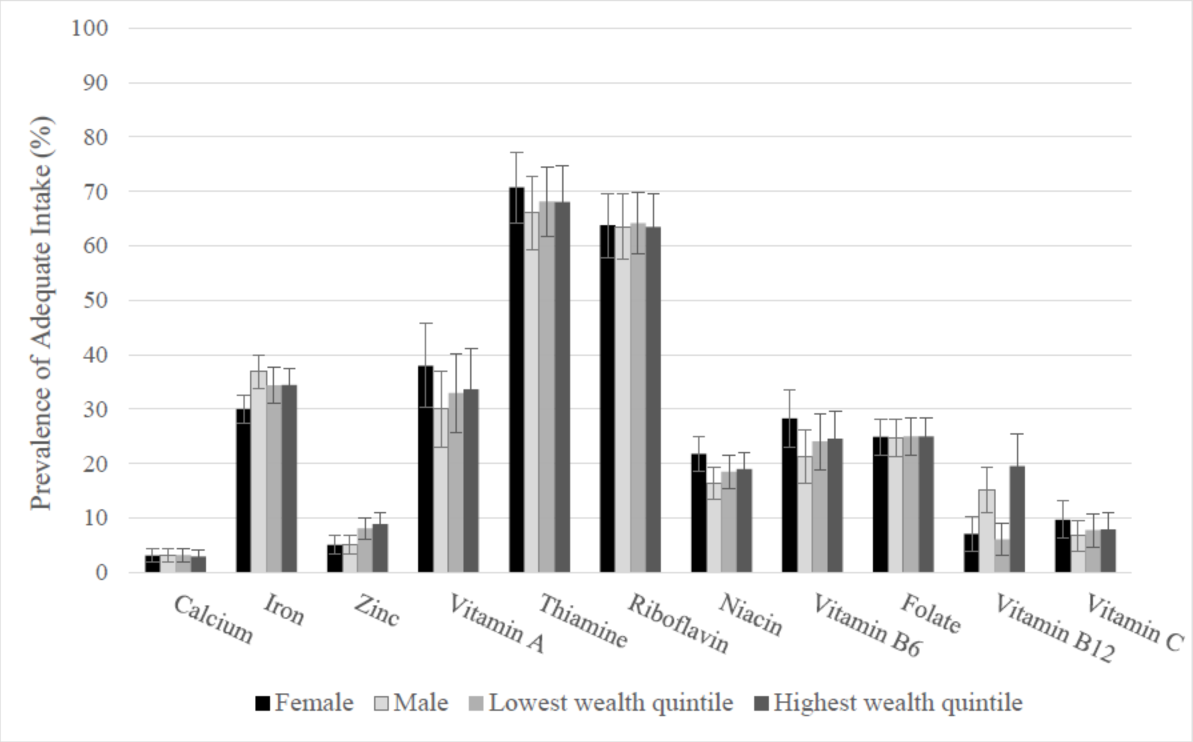


Figure 3. Prevalence of adequate intake of 11 key micronutrients among rural Sri Lankan adults by sex and wealth quintile (%, N=1283)

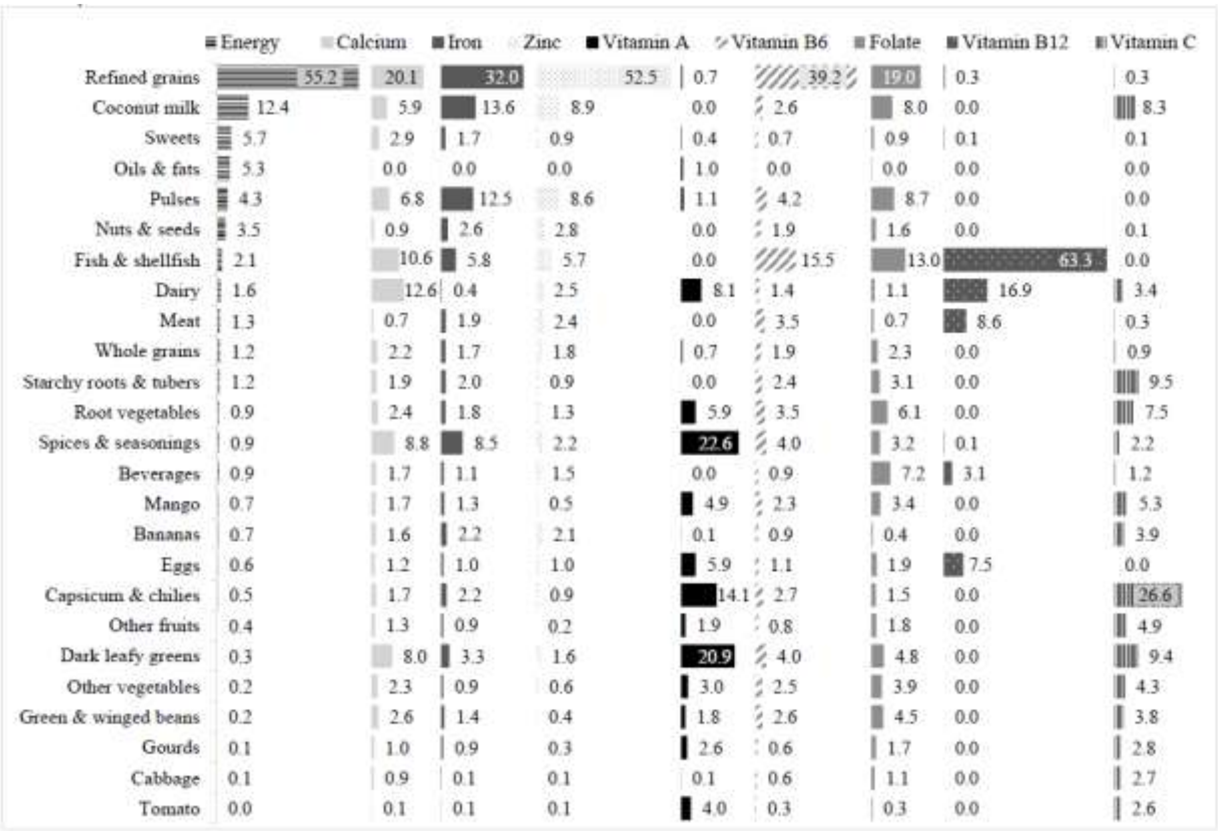


Figure 4. Relative contribution of 25 food groups to energy and micronutrient intakes among rural Sri Lankan adults (%, N=1283)

Table 1. Definition of the FRESH 14, FRESH 25, and FRESH fruits and vegetables used to assess food consumption among rural Sri Lankan adults, with comparison to the food groups used to calculate the FAO Individual Dietary Diversity Score*(23)*

Individual Dietary Diversity Score (IDDS)	**FRESH 14**	**FRESH 25**	**FRESH F&V**
Cereals	Grains	Refined grains	
		Whole grains	
Sugar/honey	Sweets	Sweets	
Milk/ milk products	Dairy	Dairy	
Meat, poultry, offal	Meat and eggs	Meat	
Eggs		Eggs	
Fish and seafood	Fish and shellfish	Fish and shellfish	
Oil/fats	Oils & fats	Oils & fats	
Pulses/ legumes/ nuts	Pulses	Pulses	
	Nuts and seeds	Nuts and seeds	
Root and tubers	Starchy roots and tubers	Starchy roots and tubers	
Miscellaneous	Coconut milk	Coconut milk	
	Beverages	Beverages	
	Spices & seasonings	Spices & seasonings	Curry leaves
Fruits	Fruits	Bananas	Bananas
		Mango	Mango
		Other fruit	Nelli
			Papaya
			Other fruits
Vegetables	Vegetables	Cabbage	Cabbage
		Capsicum & chilies	Capsicum & chilies
		Dark leafy greens	Amaranth leaves
			Cassava leaves
			Drumstick leaves
			Hummingbird tree

			leaves
			Sessile joyweed
			Water spinach
			Other dark leafy greens
		Green & winged beans	Green & winged beans
		Gourds	Pumpkin
			Other gourds
		Other vegetables	Eggplant
			Other vegetables
		Root vegetables	Carrot
			Onion
			Other root vegetable

Table 2. Baseline characteristics of rural Sri Lankan adults (N=1283) in the Resilience, Risk Reduction, Recovery, Reconstruction, and Nutrition (R5N) evaluation study (2020-2021)

Demographic characteristic	**n (%)**
Age, years, mean (SD)	45.1 (12.6)
Sex, female	486 (38.6)
District	
Batticaloa	265 (20.7)
Mannar	172 (13.4)
Matale	217 (16.9)
Monaragala	318 (24.8)
Mullaitivu	311 (24.2)
Schooling, head of household, years, mean (SD)	
No schooling	73 (5.8)
1-4	223 (17.7)
5-8	413 (32.8)
9-12	542 (43.0)
>12	10 (0.8)
Household size	4.2 (1.6)

Table 3. Estimated usual nutrient intakes and prevalence of adequate intake (PAI) of micronutrients among rural Sri Lankan adults (N=1283)

	Mean	**95% CI**	**Median**	**PAI, %**	**95% CI**
Energy (kcal)	1836.4	1793.1, 1879.7	1744.3	n/a	
Carbohydrates (g)	292.1	285.8, 298.4	278.6	n/a	
Fat (g)	56.4	54.4, 58.4	51.9	n/a	
Protein (g)	53.1	51.4, 54.7	49.7	n/a	
Calcium (mg)	353.7	339, 368.4	319.9	3.0	1.8, 4.2
Iron (mg)	10.0	9.6, 10.4	9.3	34.2	31.3, 37
Zinc (mg)	6.2	5.9, 6.4	5.7	8.4	6.5, 10.3
Vitamin A (µg RE)	501.7	431.3, 572.2	396.5	33.0	25.7, 40.3
Thiamine (mg)	2.1	1.7, 2.4	1.4	67.9	61.2, 74.5
Riboflavin (mg)	2.7	2.3, 3.1	1.8	63.6	57.6, 69.5
Niacin (mg)	8.3	8, 8.7	7.6	18.5	15.5, 21.5
Vitamin B6 (mg)	1.1	1, 1.2	0.9	23.9	18.9, 29
Folate (µg DFE)	200.5	190.1, 210.8	174.9	24.7	21.4, 28.1
Vitamin B12 (µg)	1.1	1, 1.2	0.9	12.3	8.7, 15.8
Vitamin C (mg)	42.8	39.3, 46.4	35.1	7.8	4.7, 10.9

CI, confidence interval