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EVALUATION OF NUTRIENT INTAKE GAPS AND NUTRITIONAL STATUS IN URBAN IVORIAN SCHOOL-AGED CHILDREN AND WOMEN OF REPRODUCTIVE AGE: ASSOCIATIONS WITH SOCIO-ECONOMIC STATUS

Ayling K^{1,2*}, Amino GK^{3,4}, Tiahou G⁵, Gbane M⁵,
 Bovee-Oudenhoven I¹, Talsma E² and A Melse-Boonstra²



Ayling Katie

*Corresponding author email: katie.ayling@frieslandcampina.com

ORCID: <https://orcid.org/0000-0002-3040-3703>

¹Friesland Campina, 3818 LA Amersfoort, The Netherlands

²Division of Human Nutrition and Health, Wageningen University & Research, 6708 WE Wageningen, The Netherlands

³Université Félix Houphouët-Boigny, 01 BP V 34 Abidjan 01, Côte d'Ivoire

⁴Centre Suisses de Recherches Scientifiques en Côte d'Ivoire (CSRS), Adiopodoumé, Côte d'Ivoire

⁵Ivory Coast Nutrition Society, Commune de Plateau, Boulevard Nanguy Abrogoua, BP V 47 Abidjan, Cote d'Ivoire



ABSTRACT

Little is known about dietary intake and nutrient adequacy of the Ivorian population. This study estimated the inadequacy for energy and nutrients in Ivorian school-aged children (6-12 years) and women of reproductive age (15-49 years) and explored the differences between age, sex and socio-demographics groups. A cross-sectional dietary intake study was conducted with Ivorian school-aged children (n=423) and women of reproductive age (n=423) from different households across four cities, recruited by two-stage random sampling. Dietary intake data were collected by multiple pass 24-hour recall, with a non-consecutive repeat recall day in a sub-sample (12% of subjects). By adjustment for within-person variation, usual daily nutrient intake was calculated, and the prevalence of nutrient adequacy was assessed using the Estimated Average Requirement (EAR) cut-point method (except for iron in women of reproductive age, for which the probability of adequacy method was used with the full requirement distribution). Differences between age, sex and socio-demographic variables in mean intake and prevalence of inadequacy was determined based on confidence intervals, where possible. The results show that intake of most nutrients was adequate for both school-aged children and women of reproductive age, except for calcium (99% and 96% inadequacy, respectively), riboflavin (53 and 79% inadequacy) and zinc (51 and 53% inadequacy). Older children (11-12 years) experienced higher prevalence of inadequacies than younger children (6-10 years), and for women of reproductive age, the youngest age group (15-17 years) experienced higher prevalence of inadequacies than older age groups (18-49 years). No differences were found between sexes among children. Most nutrient inadequacies showed a negative linear relationship with socio-economic status for school-aged children, where the highest inadequacies were seen in the lowest socio-economic status groups. Most school-aged children (69%) and women of reproductive age (56%) met their energy requirements. Protein intake was often below the Acceptable Macronutrient Distribution Range (AMDR) (53% children and 45% women). Ivorian nutrition policies and interventions should generally focus on improving calcium, riboflavin and zinc intake, in addition to vitamin A and folate intake specifically in older children and young women.

Key words: School-aged children, women of reproductive age, Ivory Coast, dietary intake, nutrient inadequacy

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INTRODUCTION

Globally, undernutrition is still a key concern, as it contributes to an estimated 45% of child deaths under the age of 5 years [1]. In the Ivory Coast, there appears to be a shift in malnutrition with age and time, as thinness decreases and overweight and obesity are on the rise. The Ivory Coast has a predominantly young population: children under 15 years old make up 42% of the 22 million Ivorian people. According to the USAID Demographic Health Survey (DHS) 2021, around 20% of Ivorian children under 5 years of age are stunted, 68% are anaemic and 3% overweight [2]. For children and adolescents (5-19 years), thinness has shown a downtrend to now affecting an estimated 7.5% of boys, whereas overweight and obesity has steadily increased over time and is predicted to affect 24% of girls in 2019 [3]. Similar trends are shown for women of reproductive age (20 years and older): underweight has declined to around 7%, whereas overweight and obesity have steadily increased to 39%. In addition, the prevalence of anaemia in women of reproductive age is also remarkably high at approximately 60% [2]. These nutritional issues can for a large part be addressed by adequate dietary intake.

To the best of the authors' knowledge no studies have investigated dietary intake in Ivorian school-aged children (6-12 years) and women of reproductive age (18 years and above). Identifying nutrient intake inadequacies (nutrients consumed below recommended levels) is important to better tailor nutrition interventions and ultimately to improve the health status of a population. This is especially important in the case of Ivory Coast, where there appears to be a transition in malnutrition with age and time, from undernutrition to overnutrition.

Diets in low- and middle-income countries (LMIC) are often characterised as monotonous and staple-based, leading to low dietary diversity and high micronutrient deficiencies [4]. Available data suggest that this also applies to the diets of Ivorian children and women [2]. The 2021 Demographic and Health Survey (DHS) reports low diet diversity for children aged 6-23 months, with only 24% meeting the minimum diversity criteria (five out of eight food groups) and for women aged 15-29 years, only 29% met the minimum (five out of ten food groups). A scoping review of 30 sub-national studies, including 15 from Abidjan (2000-2019), found high prevalence of iron and riboflavin deficiencies based on blood measurements in 10-19-year olds, as well as inadequate dietary intake of iron, riboflavin and vitamin A. These nutrient inadequacies were attributed to low consumption of animal foods, fruits and vegetables [5].

The purpose of this study was to fill the knowledge gap regarding dietary intake and to identify inadequate nutrients in the diet of school age children (6-12 years old) and women of reproductive age (18-49 years old) in four Ivorian cities: Bouake, Daloa,



Abengourou and Yopougon. Differences in nutrient intake inadequacy between sex, age, and socio-demographic groups were also assessed.

Methods

A cross-sectional study was conducted to assess the usual dietary intake of Ivorian school-age children and women of reproductive age. The study received ethical approval from the National Ethics and Research Committee of Côte D'Ivoire (CNER-CI). Consent for study participation was obtained from study participants for women and by parent and/or caregiver in case of the children.

Participants

The study was conducted in February 2021 with 423 school-aged children (6-12 years) and 423 women of reproductive age (15-49 years) in four cities of Ivory Coast: Bouake, Daloa, Abengourou and Yopougon. Participants were selected by a two-stage custom random sampling technique. First, neighbourhoods were selected by simple random sampling from a list of neighbourhoods in each of the cities, according to the General Population and Housing Census RGPH 2014. The number of selected neighbourhoods in a city was based on the probability proportional to size of the city. Households were then selected by using the random walk method. Participants were selected from the household if they were healthy and between the age of 6-12 or 15-49 years old. Only one child or woman was selected per household; hence, women and children did not reside in the same households. The required number of participants selected for the study was calculated based on a response rate of 90%, precision rate of 0.05, and iron as the most critical nutrient [6]. The prevalence of iron inadequacy was estimated conservatively at 50%.

Tools and procedure

Before the study, field investigators were trained on the study's tools and procedures, and a pilot study was conducted with 20 participants in Yopougon (participants were not included in the final sample). Feedback from the training and pilot study was incorporated into the tools used in the study.

All information collected in the study was through face-to-face interviews by a field investigator with the participants (6-12 years old and 15-49 years) and their main caregivers (for all children 6-12 years). Data collection was conducted with an electronic survey tool developed in KoboCollect (versions 1.25.1, KoboToolbox, USA). First, height and weight were measured using a standardized scale, height board and measuring tape. Then, a questionnaire was administered on demographic and socio-economic data. Socio-economic information included the main caregiver's educational level and occupation, living situation, number of people living in the household and daily household expenditure on food.



Dietary intake information was collected via a standard multiple pass 24-hour recall as previously described and validated for other low- and middle-income countries [6]. Participants were asked in a four-step approach to detail all foods and beverages consumed over the previous 24-hour period in and outside their home from the time of waking up the day preceding the interview to the time of waking up on the day of the interview. Details on each ingredient, their quantity and frequency of consumption were collected. Portion sizes of foods and beverages were estimated based on a photographic food atlas. The photographic food atlas was created by following the protocol from Michael Nelson *et al.* [7]. A second 24-hour recall was re-administered to 12% of the participants on non-consecutive days with at least 7 days and at most 18 days between the two recalls [6].

Calculations and statistical analysis

Nutrient intake data were generated by the software tool Compl-eat™ (Wageningen University, Wageningen, the Netherlands, Version 1.0) [8]. For this, the detailed information on consumed foods and beverages from the 24-hour recall was entered. Conversion factors and edible portion sizes were applied to calculate the actual amount of food consumed. Nutrient values of foods and beverages were taken from the West African Food Composition Table (WAFCT, 2019) [9]. Vitamin A-fortified oils specific to Ivory Coast were available, however they were not used due to significant vitamin A loss during cooking [10]. When foods, beverages or certain nutrients were not available in the WAFCT, the French Food Composition Table (CIQUAL, 2020) was used, followed by scientific literature when available [11]. For foods and meals prepared out of home and common local recipes (example sauces), the study team created standard recipes via investigation with local food vendors.

Energy and nutrients included for analysis were macronutrients: protein, fat, and carbohydrates; fibre; and 11 micronutrients: calcium, iron, zinc, vitamin A, thiamin, riboflavin, niacin, vitamin B6, folate, vitamin B12 and vitamin C. These nutrients were chosen as they are a public health concern for children and women in the West-African region and their composition and requirement information was available [12,13]. Data were cleaned by first calculating the z-scores of energy intake, after which the 24-hr recalls with z-scores higher or lower than ± 2.58 (99% confidence interval), and the highest and lowest 1% of the amounts of recalled foods were identified. These records were checked for discrepancies with the original electronic questionnaires and corrected where possible. If no discrepancies were found, the plausibility of each record was discussed with a team of experts. Ten identified records for school-aged children were judged implausible and their data were excluded, leaving a final number of 488 observations (final subject number= 434, with 54 subjects having a 2nd day record). For women of reproductive age, seven records were judged implausible and their data were excluded, leaving a final



number of observations of 486 (final subject number= 434, with 52 subjects having a 2nd day record).

Daily nutrient intakes were used to estimate the usual nutrient intake distribution and adequacy of nutrient intake of the study population with the Statistical Program to Assess Dietary Exposure (SPADE; version 4.1.1, RIVM, The Netherlands) in R Studio (Packages: SPADE.RIVM). Twelve percent of the participants had a repeat 24h recall, which allowed to adjust the nutrient intake distributions for inter-person variation. The estimates of usual nutrient intake, obtained through bootstrapped resampling techniques (200 iterations), were then used to calculate the prevalence of nutrient adequacy with corresponding 95%-confidence intervals.

Nutrient adequacy was calculated by comparing average nutrient intakes to nutrient reference values. The nutrient reference values used were the Average Requirement (AR) provided by *Allen et al. (2020)*, as these are the most up-to-date and appropriate for use as Ivory Coast does not have their own set of nutrient intake requirements [14]. By exception, iron intake adequacy in women of reproductive age, where the requirement distribution is skewed, was evaluated by using the full requirement distribution of the European Food Safety Authority (EFSA) [15]. Moderate levels of bioavailability were assumed for iron (10%) and zinc (25%) [16], based on the Human Development Index classification of Ivory Coast as "Moderate" [17]. Although average nutrient requirements are available for vitamin D, they assume no sun exposure, so we did not calculate vitamin D inadequacy. The inadequacy of iodine intake was not calculated, as insufficient information was collected on iodine fortified foods, especially on iodine fortified salt as an ingredient in meals or recipes.

The reference value for energy intake was calculated for each individual by using the Estimated Energy Requirement (EER) based on age, sex, body weight, height and physical activity level (PAL) set by IOM, where PAL was assumed to be 'low activity' for all participants. Intakes of macronutrients were also evaluated as a percentage of the total daily energy intake, and inadequacy and excessive intake were classified as less than the lower and higher than the upper limit of the Acceptable Macronutrient Distribution Range (AMDR) respectively. AMDR used for macronutrients are according to IOM, 2005 [18].

Anthropometric parameters (height and weight) were compared to healthy ranges as defined by the age and gender-specific WHO ranges. Anthropometric data of children was analysed by using the World Health Organization (WHO) Anthro Plus Software (version 1.0.4) [19]. The WHO defines obesity for children (5-19 years) as BMI-for-age greater than 2 standard deviations (SD) above the WHO growth reference median, overweight as BMI-for-age greater than 1 SD above the median,



while thinness is defined as a BMI-for-age greater than 2 SD below the median and stunting as height-for-age greater than 2 SD below the median [20]. For adults, BMI was calculated as weight in kilograms divided by height in meters squared (kg/m^2). Then, individuals were categorized based on the BMI cut-off values recommended by WHO as underweight ($<18.5 \text{ kg}/\text{m}^2$), normal ($18.5\text{--}24.9 \text{ kg}/\text{m}^2$), overweight ($25\text{--}29.9 \text{ kg}/\text{m}^2$) and obese ($\geq 30 \text{ kg}/\text{m}^2$) [21].

Differences in nutrient inadequacies by demographic characteristics (sex and age categories) were then analysed by evaluating the confidence intervals. A difference was considered significant in cases where the mean usual intake or prevalence of nutrient inadequacies did not fall within the 95%-confidence intervals of the comparison groups. In instances where sample sizes within variable groups were insufficient to permit bootstrapping, the linear relationship between nutrient inadequacies and SES variable groups was assessed by chi-square tests for trend. Homogeneity between groups (school-aged children and women of reproductive age) was also evaluated. For continuous variables (example age) independent samples t-tests were used, and categorical variables (example sex, nutritional status, sociodemographic status) were compared using chi-square tests.

RESULTS AND DISCUSSION

Demographics

In total, 45% of children (6-12 years) were male and 55% female (**Table 1**). In all age groups, most participants lived in Abidjan (36%), followed by Bouake (29%), Daloa (26) % and Abengourou (9%). The socio-demographic information of children and women was similar.

Nutritional status of Ivorian children and women

Table 1 presents the nutritional status of the Ivorian children and women participating in our study. Overall, for Ivorian children, 1.4% were obese, 5.7% were overweight, 11% were thin, and 2.5% were stunted. More female compared to male children were overweight ($p=0.02$) (Supplementary Table 1). Overall, for Ivorian women; 17% were obese, 32% were overweight, and 7% were underweight. Younger women were often more underweight ($p=0.00$) and older women more overweight and obese ($p=0.00$) (Supplementary Table 2).

Energy, nutrient intake and inadequacies in Ivorian children (6-12 years)

Table 2 shows the usual intake distributions of energy, macronutrients, and fibre, and their comparison to recommended requirements for children. Energy intake was mostly above the estimated requirement, with 31% of children not meeting their requirement. Carbohydrate intake was mostly within the respective AMDR for total



energy (56%), whereas fat intake often exceeded the upper bound (33% of children) and protein was often under the lower bound (53% of children).

Figure 1 shows that calcium, riboflavin and zinc intake did not meet the EAR for most children aged 6-12 years, with 99%, 53% and 51% of children having inadequate intakes, respectively. Children had moderate intake inadequacies for vitamin A (33%), folate (28%), vitamin B6 (24%) and vitamin C (24%). The intake of iron, thiamin, niacin and vitamin B12 met the EAR for $\geq 85\%$ of children. Supplementary Table 3 details the mean nutrient intake and prevalence of nutrient inadequacy per age group and sex. The prevalence of nutrient intake inadequacies was similar between male and female children.

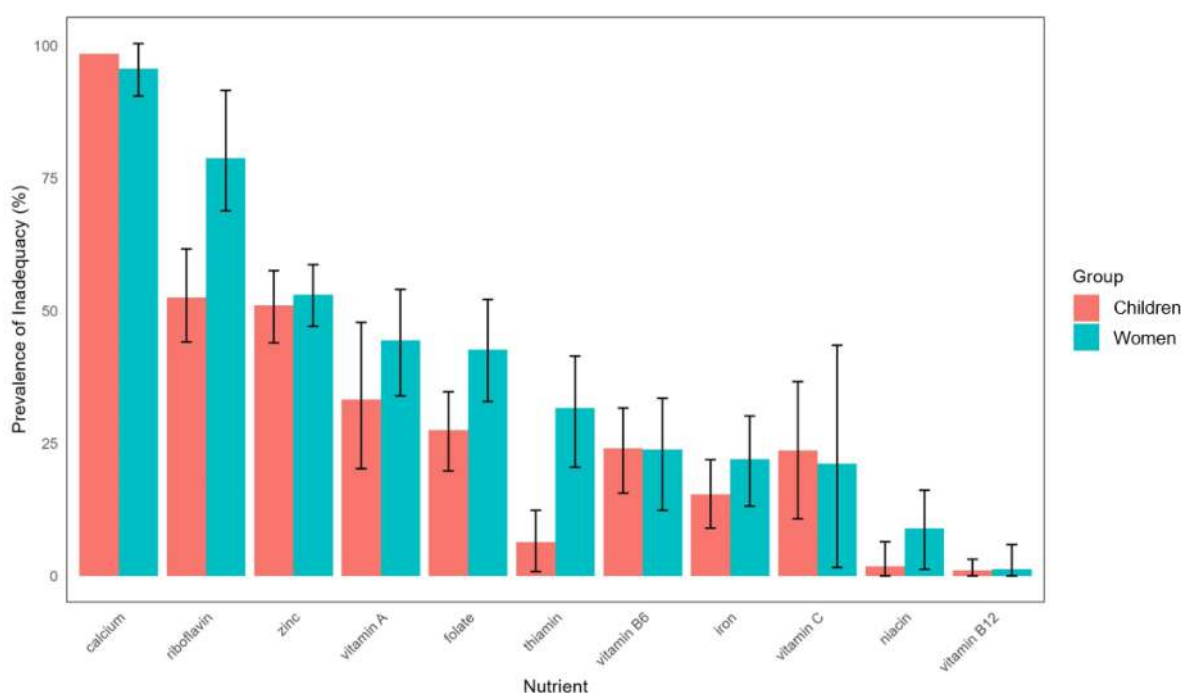


Figure 1: Prevalence of nutrient intake inadequacy of Ivorian school-aged-children (6-12 year) and women of reproductive age (15-49 years). Error bars indicate the 95% confidence intervals

As seen in **Figure 2**, the prevalence of inadequacy was highest for children aged 11-12 years old for all nutrients. Differences between the oldest age group and the two younger age groups were found for all nutrients except niacin, vitamin B12 and calcium. Differences between the eldest and middle age group were also found for niacin.

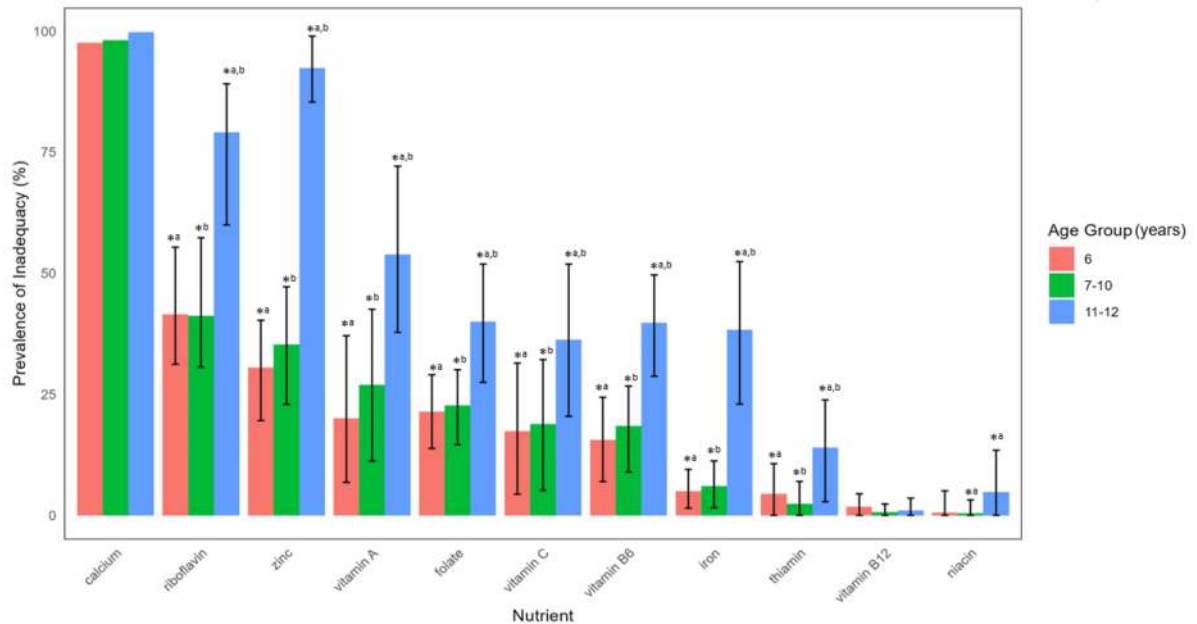


Figure 2: Prevalence of nutrient intake inadequacy by age group of Ivorian school-aged-children (6-12 years). Error bars indicate the 95% confidence intervals. Significant differences between age groups, determined using confidence interval method, are indicated by a,b. Bars that share the same letter are significantly different from each other ($p < 0.05$)

Energy, nutrient intake and inadequacies in women of reproductive age (15-49 years)

Table 3 reports the usual intake distributions of energy, macronutrients and fibre and their comparison to recommended requirements for women. Energy intake of 46% of women was below their energy requirement. Carbohydrates were mostly within the AMDR boundaries, whereas protein was often under the lower bound (45% of women) and fat exceeded the upper boundary for fat intake (35% of women). For micronutrients, Supplementary Table 4 details the mean nutrient intake and prevalence of nutrient inadequacy per age group.

Figure 1 indicates that a large proportion of women did not meet the EAR for intake of calcium (96%), riboflavin (79%), zinc (53%), vitamin A (44%) and folate (43%). Intake of thiamin, vitamin B6, iron and vitamin C was inadequate for 20-30% of women, whereas intake of niacin and vitamin B12 was mostly sufficient.

As seen in **Figure 3**, the prevalence of inadequacy was highest for women aged 15-17 years old for most nutrients. Differences were seen between the youngest age group and the two older age groups for calcium, riboflavin, zinc, vitamin A and folate

inadequacies. For vitamin B6 the difference between the youngest and the oldest age group was different.

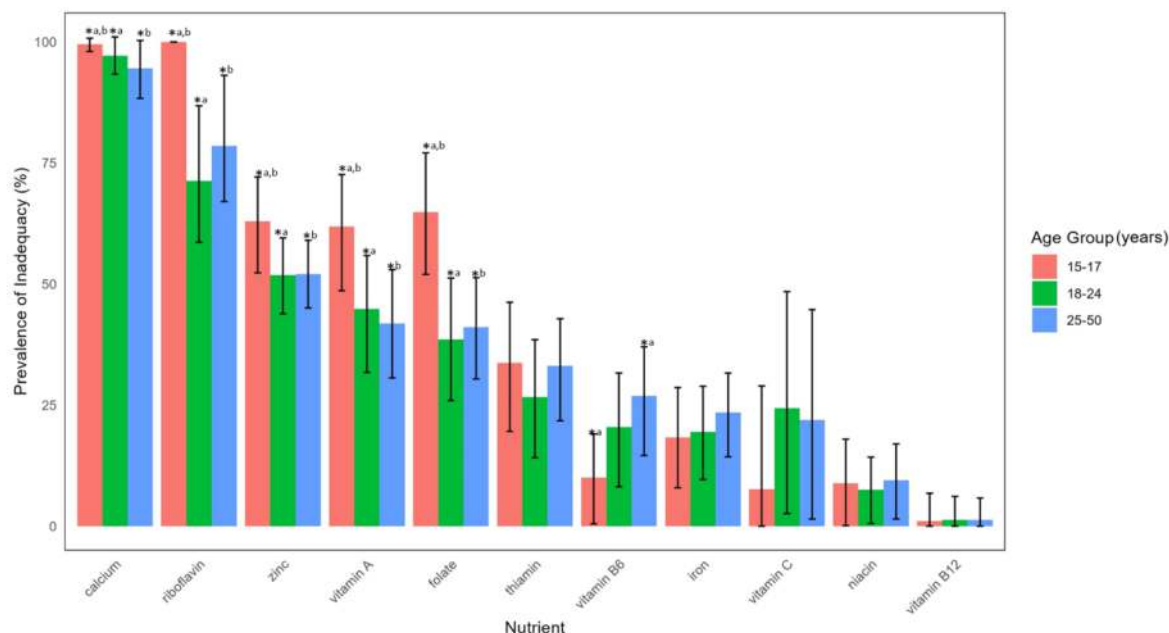


Figure 3: Prevalence of nutrient inadequacy by age group across nutrients for Ivorian women of reproductive age (15-49 years). Error bars indicate the 95% confidence intervals. Significant differences between age groups, determined using confidence interval method, are indicated by a,b. Bars that share the same letter are significantly different from each other (p < 0.05)

Comparisons of nutrient adequacy by socio-economic status (SES)

Table 4 and 5 summarise the prevalence of nutrient intake inadequacy by SES variables for school-aged children and women of reproductive age, respectively. Overall, the four different SES variables (living situation, household expenditure, occupation and school education) did not show similar trends in prevalence of nutrient inadequacies between school-aged children and women of reproductive age.

For school-aged children nutrient inadequacy roughly followed the expected negative linear relationship with SES, where the lowest SES group, had higher prevalence of nutrient inadequacies, except for folate. As seen in Table 4, most nutrient inadequacies (8 nutrients) showed a strong negative relationship with household expenditure, followed by living situation (7 nutrients), education (6 nutrients) and then occupation (3 nutrients).

For women of reproductive age, the trend for nutrient inadequacy across the four SES variables was not as expected. Majority of nutrients showed an unexpected

positive relationship with SES variables, where the highest SES groups experienced higher nutrient inadequacies, especially for living situation. This relationship was strong for 5 nutrients, as seen in Table 5, where the p -value < 0.0167 . A strong negative relationship (as expected) was also seen with nutrient inadequacies and occupation (5 nutrients), followed by household expenditure (4 nutrients), education (2 nutrients) and living situation (1 nutrient) ($p < 0.00$).

In summary it was found that both under- and over- nutrition was prevalent in children, whereas overnutrition was a major issue for women. High levels of micronutrient inadequacies were observed in both children and women, with calcium deficiency affecting over 90%, and riboflavin and zinc deficiencies affecting more than 50%. Additionally, 20-45% of both groups showed inadequacies in vitamin A, folate, vitamin B6, and vitamin C. Thiamin inadequacies were also prevalent among women. In addition, most nutrients appeared to have higher prevalence of inadequacies in older children (11-12 years) and younger women (14-17 years).

Nutrients with high prevalence's of inadequacies found in this study, were similarly seen in the other studies on children from Ivory Coast and Nigeria; a scoping review of Ivorian adolescents (10-19 years) and cross-sectional dietary intake study in Nigerian children (4-13 years) [5,22]. Calcium and riboflavin showed the highest prevalence's of inadequacies and are found in high amounts in animal products. Consumption of dairy, especially for calcium, meat, nuts and green vegetables, for riboflavin should be further explored and potentially increased in this population group.

High prevalence's of inadequate intakes of iron, zinc and vitamin A are expected in LMIC, and this indeed was the case for our study, except for iron. The Nigerian study found all three nutrients (iron, zinc and vitamin A) to be inadequate in over half of the children [22]. These nutrients are generally prioritised by national and international stakeholders in LMIC national policies and programs. Large-scale food fortification is a cost-effective example of this. In Ivory Coast, the fortification program "Ivoirien de la Promotion des Aliments Fortifiés [PIPAF]" has been implemented since 2007. Wheat is fortified with electrolytic iron and folic acid, refined vegetable oil with vitamin A and salt with iodine. These nutrients are also the focus of other nutrition initiatives as part of the countries National Multisector Nutrition Plan (2016-2020). Initiatives include iron and vitamin A supplementation of children under 5 years [23]. In this study, zinc inadequacy was found to be problematic for over half of children (6-12 years old), increasing to even 92% for older children and 53% for women. Notably zinc is not currently included in the fortification initiatives in Ivory Coast. The national mandatory fortification of vitamin A in cooking oils was found to have high compliance (97%) to the national fortification policy however compliance



was much lower for iron fortified wheat (32%) [23]. Despite this and high consumption of cooking oils, there remains high levels of vitamin A inadequacy in Ivorian children and women, this may be contributed to the high degradation of vitamin A when cooked [10].

This study found a higher prevalence of nutrient inadequacies in women compared to children, consistent with existing literature from Nigerian and South African families living in poor resource settings. In such contexts, patriarchal social structures often dictate intra-household food distribution, with adult males receiving priority, followed by male children, then female children and finally adult women [24,25]. However, this pattern does not fully explain the observed differences in nutrient inadequacies between age groups. Older children (11-12 years) and younger women (15-17 years), both in adolescence, had the highest nutrient inadequacies. This could be due to increased nutrient requirements during later childhood and adolescence.

Interestingly, there was no difference found between male and female children in energy and nutrient inadequacies. However female children had a higher prevalence of overweight and obesity ($p=0.02$), and over 50% of adult women were overweight and obese. This discrepancy may be explained by under-reporting of energy intake among females in this study, a common issue in overweight or obese populations [26]. These findings align with the Global Nutrition Report, which reports a higher prevalence of overweight or obesity among Ivorian female children, adolescents and women compared to their male counterparts [3].

Health and nutrition disparities linked to socio-economic status are well-documented in literature [27]. Identifying the SES factors contributing to these disparities within a population is crucial for developing targeted nutrition and health interventions. Similar to the literature, our study showed that lower SES was linked to higher nutrient inadequacies in children. Most nutrients showed a strong negative relationship with household food expenditure, living situation and/or school education. For women, fewer nutrients also showed a strong negative relationship with household food expenditure (similarly to children) and occupation. However, an unexpected positive relationship with SES variables was more commonly observed among women, especially for living situation. There appears to be more than one trend occurring and further exploration may be needed into the diet of women with a higher SES. In contrast to these findings, the dietary intake study in Ibadan Nigeria, showed no significant differences between SES groups, where SES was categorised based on the Market Research Society of India (MSIR) [22]. Further research may also be needed to identify more comprehensive variables for measuring SES in Ivory Coast (example Multidimensional Poverty Index (MPI)) [27].



This study is limited by the fact it did not include participants from rural areas. Current literature in the region suggests rural populations face a higher burden of child undernutrition than urban populations [28,29]. Secondly, the gold standard to assess usual nutrient intake is to conduct three 24-hour recall surveys on non-consecutive days [30,31]. For feasibility reasons this was not followed in this study, only one 24-hour recall was performed and a second repeat for 12% of the study population. Physical activity levels were also not collected and low physical activity was assumed for all participants. In addition to this, Ivory Coast does not have their own nutritional food composition table, thus instead the West African and French composition tables was used. This limits the matching of food items with accurate nutritional composition. Future research should also consider the nutrient status of the population (via collection of blood and urine markers) to further confirm the findings in this study or those that could not be included in this study (example vitamin D and iodine).

This study was the first study to investigate nutrient inadequacies in urban Ivorian school age children and women of reproductive age. Targeting the nutrients identified as inadequate could improve the effectiveness of nutrition policies, programs and interventions for these groups in Ivory Coast. Effective programs addressing calcium, riboflavin and zinc inadequacies in LMIC should be considered [32]. Nutrition education, particularly through schools could help older children and younger women to make healthier food choices. School feeding programs are an example of interventions that can be tailored to this age group and prioritise missing foods and nutrients. In 2017-2018 school feeding programs were implemented in 12% of Ivorian schools [33]. This presents great potential for lasting dietary improvements, particularly preparing young women for childbearing years, where nutritional requirements increase and directly impact the health of the unborn child. Since national fortification is already implemented in Ivory Coast (iron, folic acid, vitamin A and iodine), the fortification level, bioavailability and degradation factors (example phytates in wheat, cooking of oil) should be evaluated, along with compliance to national fortification policies.

CONCLUSION AND RECOMMENDATIONS FOR DEVELOPMENT

Overnutrition is a problem for Ivorian urban women of reproductive age and undernutrition still remains a prevalent issue in Ivorian school-age children. Majority of children and women had inadequate intakes of calcium, riboflavin and zinc. Nutrition policies, programs and interventions for Ivorian school-aged children and young women should focus on improving these nutrients. Examples include school education and feeding programs on food groups that are rich in the nutrients of



concern, and improvement of current nutrient fortification programs and consideration of including new nutrients such as zinc.

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Author Contributions

KA, IBO, GT designed research; GT, GK and MG conducted research; KA analyzed data; and KA, ET, IBO and AMB wrote the paper. KA had primary responsibility for final content. All authors read and approved the final manuscript.

Data Availability

Data described in the manuscript, code book, and analytic code will be made available upon request pending [e.g., application and approval].

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Author Disclosures

KA and IBO are employed by FrieslandCampina and were involved in study design, analysis, interpretation of data and writing of the report. Ivory Coast Nutrition Society research (GT, GK, MG) team received funding. AMB and ET: No conflict of interest.



Table 1: Demographic, socio-economic and nutritional status characteristics of school-aged children (6-12 years) and women of reproductive age (15-49 years)

Characteristic		School-aged children (n=434) %	Women of reproductive age (n=434) %
Sex	Male	45	0
	Female	55	100
Household size, n	mean \pm sd	7 \pm 4	7 \pm 4
Number of dependent children, n	mean \pm sd	4 \pm 2	3 \pm 3
Household Type, %	Monogamous	85	72
	Polygamous	10	22
	Other	5	6
Food Household Expenditure (per day), %	< 2000 Fr	26	21
	2000-4000 Fr	54	61
	> 4000 Fr	19	18
Living situation, %	Shack or common commune	48	45
	Apartment	35	36
	Villa	16	20
Marital Status, % ¹	Single	47	48
	Partnership	37	33
	Married	15	17
	Separated/Divorced	0	1
	Widow	2	2
Education, % ¹	None	16	25
	Primary	52	24
	Secondary	28	38
	Tertiary	4	14
Occupation, % ¹	Student or not employed	44	36
	Informal sector	36	50
	Manager or salary	20	15
Ethnicity, %	Akan	42	46
	Gour	4	4
	Krou	7	7
	Mande du nord	17	13
	Mande du sud	20	16
	Non-Ivorian	7	7
	Other	4	7
Nutritional status, % ²	Normal weight ^a	82	44
	Thin or underweight ^b	11	7



Stunted ^c	3	NA
Overweight ^d	6	32
Obese ^e	1	17

¹Characteristics refer to the mother or care-giver of the child ² For children z-scores cut-offs for ^aBMI/age -2SD and +1 SD, ^bBMI/age <- 2SD ^c ht/age <-2SD ^d (BMI/age >+ 1SD), ^eBMI/age >+ 2SD and for adults the Body Mass Index (BMI) (kg/m²) cut-offs were used. Not Assessed (NA)= not applicable, FR, West African Franc, conversion rate in 2021 was 0.0015 euro



Table 2: Distribution of usual intake of energy, macronutrients and fibre of Ivorian children (6-12 years)

Nutrient (unit)	Age group (years)	Mean ± SD ¹	5 th Percentile	10 th Percentile	25 th Percentile	50 th Percentile	75 th Percentile	90 th Percentile	95 th Percentile	% < requirement ² /AMDR ³	% > AMDR ³
Energy (kcal)	6-12	2120 ± 766	1400	1538	1785	2084	2417	2749	2962	31	69
	6	1982 ± 1212	1302	1434	1672	1951	2258	2576	2767	33	67
	7-11	2117 ± 959	1414	1547	1794	2085	2410	2725	2928	31	69
	11-12	2239 ± 1217	1500	1640	1894	2203	2548	2893	3099	32	68
Protein (g)	6-12	53 ± 26	35	38	44	52	61	71	77	53	0
	6	49 ± 44	33	35	41	48	56	65	71	56	0
	7-11	53 ± 29	35	38	44	52	61	70	76	54	0
	11-12	57 ± 46	37	40	47	55	65	75	82	49	0
Fat (g) ⁴	6-12	74	47	56	67	74	79	92	106	34	33
	6	70	49	59	67	69	69	87	103	40	27
	7-11	74	47	56	71	74	77	92	105	30	35
	11-12	78	45	54	71	79	82	95	109	40	32
Carbohydrate (g)	6-12	74	47	56	67	74	79	92	106	17	27
	6	280 ± 169	166	188	227	273	325	381	421	13	27
	7-11	298 ± 138	182	204	243	290	345	402	442	16	23
	11-12	315 ± 212	197	217	257	306	363	426	466	19	34
Fibre (g) ⁴	6-12	25	16	19	22	25	28	30	34	NA	NA
	6	24	17	20	22	23	23	28	33	NA	NA
	7-11	25	16	19	24	25	27	30	34	NA	NA
	11-12	27	16	19	24	28	29	31	36	NA	NA

¹Standard deviation is calculated by the formula = ((Upper bound confidence interval - Lower bound confidence interval) / 2) / 1.96 * √ (sample size)

²Estimated energy requirement; EER males (6-12 years)= 88.5-(61.9×age)+PA×[(26.7×weight(kg))+(903×height(m))]+20 or 25 and EER females (6-12 years)=

135.3-(30.8×age)+PA×[(10.0×weight(kg))+(934×height(m))]+20 or 25; ³AMDR used for macronutrients are according to IOM, 2005; protein (10-30%), fat (25-35%) and carbohydrate (45-65%);

⁴Bootstrapping could not be performed due high within-individual variance and low between individual variance, therefore no SD could be given, as a confidence interval was not provided

Abbreviations : AMDR- Acceptable Macronutrient Distribution Range ; SD- standard deviation



Table 3: Distribution of usual energy and macronutrient intake of Ivorian women of reproductive of age (15-49 years)

Nutrient (unit)	Age group (years)	Mean ± SD ¹	5 th Percentile	10 th Percentile	25 th Percentile	50 th Percentile	75 th Percentile	90 th Percentile	95 th Percentile	% < requirement ² /AMDR ³	% > AMDR ³
Energy (kcal)	15-49	2672 ± 1358	1305	1525	1962	2543	3240	3981	4471	46	54
	15-17	2871 ± 3125	1461	1660	2135	2728	3468	4254	4734	38	63
	18-24	2802 ± 2047	1373	1609	2080	2672	3379	4164	4682	39	61
	25-49	2600 ± 1577	1274	1484	1903	2474	3153	3880	4346	50	50
Protein (g)	15-49	71 ± 38	38	43	53	67	84	103	115	45	2
	15-17	72 ± 67	39	43	54	68	86	104	116	55	0
	18-24	71 ± 50	38	43	54	68	85	104	117	48	0
	25-49	70 ± 46	37	43	53	67	84	102	114	42	2
Fat (g)	15-49	94 ± 68	57	64	76	92	110	129	141	20	35
	15-17	104 ± 123	66	72	85	101	121	141	153	15	43
	18-24	101 ± 91	62	69	82	98	116	136	149	20	36
	25-49	91 ± 75	55	62	73	88	106	124	135	21	33
Carbohydrate (g)	15-49	370 ± 200	162	195	261	350	458	571	645	19	22
	15-17	397 ± 589	183	212	284	375	488	608	681	10	23
	18-24	388 ± 320	170	206	277	367	476	596	675	18	23
	25-49	360 ± 237	157	189	253	341	446	557	629	20	21
Fibre (g)	15-49	33 ± 20	14	17	23	31	41	51	59	NA	NA
	15-17	35 ± 41	15	18	25	33	43	55	62	NA	NA
	18-24	34 ± 30	14	18	24	32	42	54	61	NA	NA
	25-49	32 ± 22	13	16	22	30	40	50	57	NA	NA

¹Standard deviation is calculated by the formula = ((Upper bound confidence interval - Lower bound confidence interval) / 2) / 1.96 * √ (sample size)

²Requirement= Estimated energy requirement, EER=354-(6.91×age(years))+PA×[(9.36×weight(kg)) + (726×height (m))]; ³AMDR used for macronutrients are according to IOM, 2005; protein (10-35%), fat (20-35%) and carbohydrate (45-65%). Abbreviations: AMDR- Acceptable Macronutrient Distribution Range, SD- standard deviation



Table 4: Prevalence of nutrient inadequacy across socio-economic levels of household expenditure, school education, occupation and living situations for Ivorian School-aged Children (6-12 years)

SES level	Household Expenditure				School education				Occupation				Living Situation			
	Lowest	Middle	Highest	p value	Lowest	Middle	Highest	p value	Lowest	Middle	Highest	p value	Lowest	Middle	Highest	p value
Calcium	100	99	97	<0.00*	100	98	100	0.71	96	99	97	0.12	99	99	90	<0.00
Folate	11	29	30	<0.00*	27	27	34	0.02	30	22	36	0.05	33	23	19	<0.00
Iron	19	18	7	<0.00*	28	15	0	<0.00	18	14	23	0.05	24	3	10	<0.00
Niacin	9	3	0	<0.00*	2	4	3	0.70	3	2	3	0.83	6	0	4	0.13
Vitamin A	41	38	0	<0.00*	46	34	21	<0.00	39	33	36	0.29	36	20	34	0.46
Riboflavin	46	46	45	0.95	73	55	42	<0.00	61	44	46	<0.00	67	42	37	<0.00
Thiamin	15	7	4	<0.00*	17	7	12	0.02	8	5	11	0.06	15	0	0	<0.00
Vitamin B12	8	1	3	<0.00*	0	3	1	0.76	3	0	0	<0.00	1	5	0	0.62
Vitamin B6	26	28	6	<0.00*	34	28	25	<0.00	30	18	19	<0.00	33	21	7	<0.00
Vitamin C	35	20	34	0.82	23	23	16	<0.00	20	22	19	0.50	28	28	0	<0.00
Zinc	53	47	34	<0.00*	67	46	59	0.0	49	47	49	0.84	45	36	38	0.04

p value: Comparison of the percent of children below the EAR across the three socio-economic levels were conducted by chi-square trends * indicates $p < 0.0167$. Yellow represents a negative relationship, where the lowest SES level has the highest nutrient inadequacies, followed by the middle and highest levels. Grey indicates a positive relationship, with the highest SES level having the highest nutrient inadequacies, followed by the middle and lowest levels. Bonferroni correction was applied to adjust for multiple group comparisons. For household expenditure, Lowest= <2000 Fr, Middle= 200-400 Fr, and Highest= >4000 Fr; for School Education, Lowest= no education, Middle= primary, and Highest= secondary; for Occupation, Lowest= not employed or student, Middle= informal sector, and Highest= salary or manager; for Living Situation, Lowest= shack or commune, Middle= apartment, and Highest= villa. FR, West African Franc, conversion rate in 2021 was 0.0015 euro



Table 5: Prevalence of nutrient inadequacy across socio-economic levels of household expenditure, school education, occupation and living situations for Ivorian Women of Reproductive Age (15-49 years)

SES level	Household Expenditure				School education				Occupation				Living Situation			
	Lowest	Middle	Highest	<i>p</i> value	Lowest	Middle	Highest	<i>p</i> value	Lowest	Middle	Highest	<i>p</i> value	Lowest	Middle	Highest	<i>p</i> value
Calcium	92	97	96	0.01	93	93	98	0.00	99	94	95	0.00	97	91	100	0.03
Folate	58	54	42	<0.00*	48	38	57	0.01*	59	51	36	<0.00*	41	64	70	<0.00*
Iron	22	19	13	<0.00*	21	10	15	0.03	23	18	11	<0.00*	13	26	24	<0.00*
Niacin	25	7	0	<0.00*	7	19	11	0.05	8	10	9	0.55	8	18	11	0.12
Vitamin A	53	35	50	0.31	16	61	58	<0.00*	61	37	60	0.84	30	64	52	<0.00*
Riboflavin	89	85	90	0.47	84	90	91	<0.00*	92	83	89	0.14	82	87	100	<0.00*
Thiamin	44	32	37	0.04	40	22	24	0.00*	35	34	27	0.02	24	45	42	<0.00*
Vitamin B12	4	7	6	0.30	4	9	7	0.08	5	4	16	<0.00*	3	3	12	<0.00*
Vitamin B6	21	15	13	<0.00*	11	14	14	0.16	23	15	7	<0.00*	16	16	12	0.13
Vitamin C	27	12	35	0.01*	23	9	8	<0.00*	31	16	8	<0.00*	21	6	2	<0.00*
Zinc	56	48	60	0.25	51	40	55	0.25	58	49	35	<0.00*	43	59	61	<0.00*

p value: Comparison of the percent of children below the EAR across the three socio-economic levels were conducted by chi-square trends, * indicates $p < 0.0167$. Bonferroni correction was applied to adjust for multiple group comparisons. For household expenditure, Lowest= <2000 Fr, Middle= 200-400 Fr, and Highest= >4000 Fr; for School Education, Lowest= no education, Middle= primary, and Highest= secondary; for Occupation, Lowest= not employed or student, Middle= informal sector, and Highest= salary or manager; for Living Situation, Lowest= shack or commune, Middle= apartment, and Highest= villa. FR, West African Franc, conversion rate in 2021 was 0.0015 euro



REFERENCES

1. **Black RE, Victora CG, Walker SP, Bhutta ZA, Christian P, De Onis M, Ezzati M, Grantham-McGregor S, Katz J, Martorell R and R Uauy** Maternal and child undernutrition and overweight in low-income and middle-income countries. *The Lancet*. 2013; **382(9890)**: 427–51.
2. **National Institute of Statistics/ Institut National de la Statistique (INS)**. Côte d'Ivoire 2021 DHS report. Rockville, Maryland, USA ; 2021 Dec.
3. **Development Initiatives**. Global Nutrition Report. Bristol, UK ; 2021.
4. **Rohner F, Northrop-Clewes C, Tschannen AB, Bosso PE, Kouassi-Gohou V, Erhardt JG, Biebinger R, Barba J, Kraemer K and RF Hurrell** Prevalence and public health relevance of micronutrient deficiencies and undernutrition in pre-school children and women of reproductive age in Côte d'Ivoire, West Africa. *Public Health Nutrition*. 2014; **17(9)**: e44–53.
5. **Jesson J, Kouakou EKV, Kumaran K, Adonis L, Wrottesley SV and V Leroy** A scoping review of literature describing the nutritional status and diets of adolescents in Cote d'Ivoire. *Public Health Nutrition*. 2020; **24(16)**: 5261–76.
6. **Gibson RS and EL Ferguson** An interactive 24-hour recall for assessing the adequacy of iron and zinc intakes in developing countries. Washington (DC): International Food Policy Research Institute (IFPRI) and International Center for Tropical Agriculture (CIAT); 2008.
7. **Nelson M and J Haraldsdóttir** Food photographs: practical guidelines II. Development of photographic atlases for assessing food portion. *Public Health Nutrition*. 1998; **1(4)**: 231–7.
8. **Meijboom S, van Houts-Streppel MT, Perenboom C, Siebelink E, van de Wiel AM, Geelen A and EJM Feskens** Evaluation of dietary intake assessed by the Dutch self-administered web-based dietary 24-h recall tool (Compleat™) against interviewer-administered telephone-based 24-h recalls. *Journal of nutritional science*. 2017; **19(6)**: e49.
9. **Food and Agriculture Organization (FAO)**. Food composition table for West Africa. Rome; 2019.
10. **Klein A** Bachelor thesis Nutrition & Health: Retention of beta-carotene in red palm oil. Wageningen ; 2016.



11. **Agence nationale de sécurité sanitaire de l'alimentation de l'environnement et du travail (ANSES).** CIQUAL French Food Composition Table. 2020. <https://www.anses.fr/en/content/table-nutritional-composition-foods-ciqual-anses-supplements-its-data-and-publishes-its-wo-0> Accessed April 2022.
12. **Torheim LE, Ferguson EL, Penrose K and M Arimond** Women in resource-poor settings are at risk of inadequate intakes of multiple micronutrients. *The Journal of nutrition*. 2010; **140(11)**: 2051S-8S.
13. **Harika R, Faber M, Samuel F, Mulugeta A, Kimiywe J and A Eilander** Are Low Intakes and Deficiencies in Iron, Vitamin A, Zinc, and Iodine of Public Health Concern in Ethiopian, Kenyan, Nigerian, and South African Children and Adolescents? *Food and Nutrition Bulletin*. 2017; **38(3)**: 405–27.
14. **Allen LH, Carriquiry AL and SP Murphy** Perspective: Proposed Harmonized Nutrient Reference Values for Populations. *Advances in nutrition*. 2020; **11(3)**: 469–83.
15. **de Jong MH, Melse-Boonstra A, Geleijnse JM and J Verkaik-Kloosterman** Assessment of the prevalence of inadequate iron intakes in premenopausal females based on the reference values of the European Food Safety Authority using cross-sectional food consumption data. *American Journal of Clinical Nutrition*. 2024; **120(1)**: 211–6.
16. **Food and Agriculture Organization (FAO), World Health Organization (WHO).** Guidelines on food fortification with micronutrients. Rome. 2006.
17. **United Nations Development Programme.** Human Development Index (HDI): Côte d'Ivoire. 2023.
18. **Institute of Medicine (IOM).** Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids (Macronutrients). Washington, DC: The National Academies Press. National Academies Press. 2005. 1–1331 p.
19. **World Health Organization.** WHO AnthroPlus for personal computers: Software for assessing growth of the world's children and adolescents. Geneva: WHO; 2009.
20. **de Onis M, Borghi E, Arimond M, Webb P, Croft T, Saha K de Benoist B, Rawat R, Rogers B and M Young** Prevalence thresholds for wasting, overweight and stunting in children under 5 years. *Public Health Nutrition*. 2019; **22(1)**: 175–9.



21. **World Health Organization (WHO).** A healthy lifestyle - WHO recommendations [Internet]. 2010.
22. **Tassy M, Eldridge AL, Sanusi RA, Ariyo O, Ogundero A, Eyinla TE, Sonibare O, Omotayo MO, Owoeye IO and BO Ogunba** Nutrient Intake in Children 4–13 Years Old in Ibadan, Nigeria. *Nutrients*. 2021; **Vol 13**, Page 1741. 2021; **13(6)**: 1741.
23. **Rohner F, Leyvraz M, Konan AG, Esso LJCE, Wirth JP, Norte A, Rohner-Boudo SM, Aaron GJ, Williams TN and L Kessler** The Potential of Food Fortification to Add Micronutrients in Young Children and Women of Reproductive Age – Findings from a Cross-Sectional Survey in Abidjan, Côte d'Ivoire. *PLOS ONE*. 2016; **11(7)**: e0158552.
24. **Fadare O, Mavrotas G, Akerele D and M Oyeyemi** Micronutrient-rich food consumption, intra-household food allocation and child stunting in rural Nigeria. *Public Health Nutrition*. 2019; **22(3)**: 444–54.
25. **Bargain O, Kwenda P and M Ntuli** Gender bias and the intrahousehold distribution of resources: Evidence from African nuclear households in South Africa. *Journal of African Economies*. 2018; **27(2)**: 201–26.
26. **Karelis AD, Lavoie ME, Fontaine J, Messier V, Strychar I, Rabasa-Lhoret R and M Brochu** Anthropometric, metabolic, dietary and psychosocial profiles of underreporters of energy intake : a doubly labeled water study among overweight/obese postmenopausal women--a Montreal Ottawa New Emerging Team study. *European Journal of Clinical Nutrition*. 2010; **64(1)**: 68–74.
27. **UNDP (United Nations Development Programme), OPHI (Oxford Poverty and Human Development Initiative).** Global Multidimensional Poverty Index (MPI): Unpacking deprivation bundles to reduce multidimensional poverty. Human Development Reports. New York; 2023.
28. **Headey D, Stifel D, You L and Z Guo** Remoteness, urbanization, and child nutrition in sub-Saharan Africa. *Agricultural Economics*. 2018; **46(6)**:765–75.
29. **Novia P, Insani C, Rimbawan R and E Palupi** Dietary habits and nutritional status among school children in rural and urban areas: A comparative study from Bogor, Indonesia. *Research Paper Future of Food: Journal on Food, Agriculture and Society*. 2018; **6(2)**.

30. **Shamah-Levy T, Rodríguez-Ramírez S, Gaona-Pineda EB, Cuevas-Nasu L, Carriquiry AL and JA Rivera** Three 24-Hour Recalls in Comparison with One Improve the Estimates of Energy and Nutrient Intakes in an Urban Mexican Population 1-3. *The Journal of Nutrition Nutritional Epidemiology*. 2016; **146(6)**: 1043–50.
31. **Institute of Medicine (IOM)**. Using the Estimated Average Requirement for Nutrient Assessment of Groups [Internet]. Washington, DC: National Academies Press (US); 2000.
32. **Lopez de Romaña D, Greig A, Thompson A and M Arabi** Successful delivery of nutrition programs and the sustainable development goals. *Current Opinion in Biotechnology*. 2021; **70:97–107**.
33. **The Global Child Nutrition Foundation (GCNF)**. Côte d'Ivoire: National School Meal Program (Country Report). 2019.

