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Dietary Patterns and Nutrient Consumption among Non-Pregnant, Non-Lactating Women of Reproductive Age in Mbeya, Tanzania: Findings from Repeated 24-Hour Dietary Recalls

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Abstract

Insufficient levels of essential micronutrients negatively impact the well-being of females in their childbearing years, affect fetal development during gestation, and influence the physical and cognitive progress of children in nations across sub-Saharan Africa. This research sought to assess nutrient consumption patterns in females who are neither pregnant nor breastfeeding, living in seven administrative areas within Tanzania's Mbeya area, through the application of a single-day food recall method. The investigation involved a survey across different locations with 500 such females. Selection occurred in two phases: three community units per area were picked based on population size proportionality, followed by random choice of 24 qualifying residences from each selected unit. Statistical software macros in SAS (release 9.4) processed consumption amounts and determined typical consumption levels for three commonly enriched food items. Average daily consumption stood at 36.47 grams for cooking oil, 110.53 grams for wheat-based flour, and 2,169.9 kilocalories overall. Protein consumption averaged 63.5 grams, exceeding the advised 56.0 grams. For trace elements, zinc showed the greatest rate of insufficient consumption (91.2%), then iron (82.2%), and vitamin B12 (80.0%). The largest shortfall relative to needs was for vitamin E (50.7%), whereas the lowest quartile shortfall was minimal (9.8%). Moderate rates of insufficient consumption appeared for vitamin C (46.5%) and riboflavin (54.8%), with a 42% shortfall in the lowest quartile. Levels of insufficient consumption for vitamin A, thiamine, niacin, vitamin B6, and folate were in the moderate range (32.6% to 44.4%), accompanied by lowest-quartile shortfalls of 16.2% to 34%. Results indicate widespread shortfalls in trace nutrient consumption among these females. Moreover, enriching cooking oil emerges as a viable strategy, though enriched wheat flour demonstrated poor penetration in this Tanzanian area.

Keywords: Dietary patterns, Nutrient consumption, Childbearing periods, Essential trace nutrients

Introduction

Shortfalls in essential trace nutrients adversely influence the overall condition of females during childbearing periods, gestational results, and the maturation and advancement of their children [1]. Such females face heightened vulnerability owing to low nutrient ingestion, uneven household food allocation, cultural practices, and biases favoring males that compel females to place household needs above their own [2].

Globally, approximately three billion individuals lacked access to nutritious meals in 2021 [3]. Diets lacking in trace nutrients significantly drive these shortfalls, remaining a key issue in emerging nations like Tanzania [4]. Deficiencies in iron, vitamin A, iodine, and zinc rank among primary contributors to illness and death in females of childbearing age in resource-limited settings [5, 6]. These issues carry lasting effects on well-being, cognitive capacity, and economic output. In Tanzania,

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the most frequently noted deficiencies include Iron Deficiency Anaemia (IDA), Iodine Deficiency Disorders (IDD), and Vitamin A Deficiency (VAD), per the Tanzania Demographic and Health Survey (TDHS) [7]. Additional concerns encompass zinc, folic acid, calcium, and certain B-group vitamins (B12 and niacin), as noted in TDHS reports [8]. Anaemia affects 45% of females aged 15–49 in Tanzania, rising sharply to 57% during gestation [9, 10]. The TDHS also indicated Vitamin A shortfall in 36% of these females. While the link between Vitamin A shortfall and anaemia requires further clarification, it potentially impairs erythrocyte formation [11].

Females in childbearing years constitute 48% of Tanzania's adult female demographic, with a fertility rate of 4.39 [7, 12]. Deficits in energy and protein, alongside trace nutrient shortfalls, frequently occur in females who are neither pregnant nor breastfeeding, raising notable public health risks [1]. Across Africa, studies reveal that eating habits vary due to traditions, location, and food choices [13–18]. Females from lower socioeconomic groups experience greater impacts [14–19]. Given infrequent and limited-scope national monitoring in the nation, targeted assessments provide rapid insights into specific group diets.

Data on consumption of foods and nutrients remain scarce in many sub-Saharan nations, Tanzania included [6, 13, 15, 19]. Such data are vital for assessing energy levels, major nutrients (fats, proteins, carbohydrates), trace elements (key vitamins and minerals), food categories, and enrichment efforts. This evidence supports evidence-based strategies and initiatives to enhance nutrient consumption, eating habits, and nutritional health overall [6, 13, 15, 19]. Accordingly, this investigation focused on evaluating and outlining patterns of food and nutrient consumption in females aged 15–49 who are neither pregnant nor breastfeeding across seven areas in Tanzania's Mbeya region.

Materials and Methods

Ethical statement

Approval for this research came from the National Health Research Ethics Review Committee (NatHREC) under the National Institute for Medical Research, registration NIMR/HQ/R.8a/Vol.IX/3964. Every individual involved gave informed written agreement before involvement, without any monetary reward. For those below 18 years, agreement was also secured from parents or guardians in writing. Personal details were de-identified, with plans for permanent deletion upon project completion.

Study design and study population

The research employed a survey across locations in Tanzania's Mbeya area, carried out between July and September 2022. Participants included females aged 15 to 49 who were neither pregnant nor breastfeeding, drawn from the region's seven areas: Chunya DC, Mbeya DC, Mbeya City, Mbarali DC, Kyela DC, Rungwe DC, and Busokelo DC.

Sample size and sampling procedures

For ensuring statistical robustness, the study targeted a predetermined representative group of 504 females aged 15–49 who were neither pregnant nor breastfeeding; ultimately, 500 consented to take part (achieving a 99.2% participation rate). This final figure of 500 aligned adequately with the initial computation derived from the Lwanga and Lemeshow approach [20]. The estimation incorporated an assumed prevalence of 50%, a margin of error of 5%, a confidence interval of 95%, and a design effect of 2. An extra 10% buffer was included to accommodate possible refusals or challenges in communication arising from health issues. Individuals residing in refugee settlements were not included, as they were not considered longstanding inhabitants of the Mbeya area.

Participant recruitment followed a two-phase cluster sampling strategy. During the initial phase, three community enumeration units per administrative area were selected via probability proportional to size (PPS) sampling. In the subsequent phase, 24 qualifying residences were chosen at random from each selected unit, drawing from an exhaustive roster of households in that unit. Prior to commencing fieldwork, the research team collaborated with community authorities to compile lists of all potentially eligible residences. Within each chosen residence, one qualifying female in the specified age range who was neither pregnant nor breastfeeding was intentionally recruited for the interview. Additionally, a subgroup of 100 individuals—representing 20% of the total sample—was designated for a second 24-hour food recall. Roughly five individuals from each enumeration unit were randomly chosen for this follow-up recall, conducted 3 to 8 weekdays following the first assessment [21–23].

Data collection

Information was gathered by 14 fieldworkers who had received specialized training, employing a set of tools that included a household survey instrument tailored for these females, a single-day dietary recall form, and a measurement sheet for body dimensions. The household section captured socioeconomic and background details for the participant and her family unit. Dietary information on all items eaten and beverages taken was obtained through the 24-hour recall tool. Questionnaires were digitized on tablets using the Open Data Kit platform through Kobo Toolbox, with data later transferred to Excel and Stata for validation and processing. Backup paper versions were kept on hand. The original English instrument was rendered into Swahili and then reverse-translated by independent experts to verify fidelity. As Swahili is Tanzania's national language and fluently understood by more than 95% of the population, it was deemed suitable. The finalized Swahili version underwent thorough scrutiny to confirm linguistic precision and cultural suitability, maintaining conceptual equivalence with the source. The tool was then pilot-tested among 57 similar females aged 15–49 in Ubungo District, Dar es Salaam, where it achieved a 95% completion rate. This pre-testing phase evaluated translation clarity, ease of understanding, and overall appropriateness for establishing face validity.

Data cleaning and preparation

Field staff transformed reported serving sizes into gram weights by applying factors from a custom photographic guide developed specifically for the project, which provided standardized weights for listed items [21]. For any items absent from the guide, conversion relied on multiplying declared volumes by established density figures from the Food and Agriculture Organization (FAO) and the United States Department of Agriculture (USDA).

Food matching, data quality control and validation

From recipe-based entries, 66 unique base foods were isolated; proportional contributions of each ingredient were determined to derive the amount of each cooked component consumed, based on the total recipe quantity reported. Another 71 foods reported directly (such as fresh avocado, uncooked rice, or sugar) were paired one-to-one with entries in the food composition database, accepting the survey-reported amounts as consumed. An automated Visual Basic for Applications (VBA) macro in Excel was created to streamline identification of each listed food and calculation of its intake quantity. These base foods were then aligned with four separate nutrient databases: two Tanzanian (one reflecting non-enriched oil and flour, the other enriched versions) and two Ugandan (similarly divided by enrichment status). Foods absent from the primary Tanzanian database were cross-referenced with composition data from Kenya, Malawi, or the United States as relevant. At the study's outset, no current comprehensive Tanzanian food composition table existed. Employing multiple databases strengthened the reference framework. This strategy provided broader coverage of nutrients and typical East African dietary items, enhancing result reliability and reflecting careful methodological planning. Nonetheless, variations in analytical techniques, nutrient reporting, and unit standardization across sources represent potential constraints. Nutrient totals were evaluated against harmonized average requirements (H-AR) for most elements, while energy, carbohydrates, and dietary fibre used national benchmarks adjusted for age. Intake was classified as insufficient when falling short of these standards. **Table 1** displays the H-AR values alongside the applicable national references.

Table 1. Recommended Daily Allowance (RDA) and harmonized average requirement values by age group

Nutrients	Adolescents Aged 15–19 Years	Women Aged 20–49 Years
Macronutrients (RDA) *		
Energy (kilocalorie [kcal])	2200	2100
Protein (g) (H-AR)	(0.8 X 60 kilogram (kg)** = 48 g/day)	(0.8 X 70 kg*** = 56 g/day)
Micronutrients (H-AR Values)		
Vitamin A retinol activity equivalent (RAE) (microgram [µg])	490	490
Vitamin B1—Thiamine (milligram [mg])	0.9	0.9
Vitamin B2—Riboflavin (mg)	1.4	1.3
Vitamin B3—Niacin (mg)	11	11
Vitamin B6 (mg)	1.3	1.3
Vitamin B12 (µg)	2	2
Vitamin C (mg)	75	80
Vitamin E (mg)	12	12

Copper (µg)	685	700
Folate dietary folate equivalent (µg)	250	250
Iron (mg) (low absorption—5 percent)	22.4	22.4
Zinc (mg) (unrefined diet, 1200 mg phytate/day in the diet)	10.2	10.2

* Ryan-Harshman and Aldoori 2006
** The average weight of women in Tanzania aged 15 to 19 years old (MoH 2023)
*** the average weight of women in Tanzania aged 20–49 years old (MoH 2023)

Data analysis

Consumption quantities (in grams) were calculated for key fortification vehicles, including cooking oil, wheat flour, sugar derived from home-prepared dishes, and sugar originating from commercially produced foods or drinks. Fortificant levels from the Tanzanian Food Composition Table (TFCT) and Uganda Food Composition Table (UFCT) were applied to assess the proportion of insufficient vitamin A intake under scenarios with fortified oil, as well as the proportion of inadequate levels for selected vitamins and minerals (vitamin B12, folate, iron, and zinc) under scenarios with fortified wheat flour.

As presented in **Table 2**, contributions of additional vitamins or minerals from enriched foods were derived by multiplying the quantity of each fortified vehicle consumed by the specified nutrient addition during the fortification process. Standards from the East African Community for fortification were followed, incorporating estimated losses from production to point of consumption. A 30% reduction at the household level was applied for vitamin A in oil, while a 15% reduction was used for vitamin B12 and folate in wheat flour. Nutrient profiles for individual food items were established separately using the TFCT and UFCT. For each item, the reported consumption amount was multiplied by its base nutrient content and then adjusted by the relevant USDA nutrient retention factor corresponding to the reported preparation method, followed by division by 100 to yield final intake in grams.

The nutrient shortfall in the lowest quartile (Q1) was computed by subtracting the estimated usual intake at Q1 from the absolute H-AR value. This shortfall was then converted to a percentage of the H-AR through the formula: [(absolute shortfall at Q1 / H-AR value) × 100]. For energy, the Recommended Daily Allowance (RDA) served as the reference in place of H-AR, as the latter was unavailable. The likelihood of meeting requirements for key nutrients—including energy, protein, and 12 micronutrients—was estimated using SAS Studio version 9.4 (SAS Institute Inc., 2013). Given the skewed distribution of iron requirements, evaluation of iron adequacy employed the Simulating Intake of Micronutrients for Policy Learning and Engagement (SIMPLE) macro developed by the University of California, Davis.

Table 2. Quantities of added micronutrients during industrial fortification and projected reductions at the domestic stage

Fortified Vehicle	Nutrient	Projected Reduction at Household Stage (%)	Quantity Added During Processing (mg/100 g)
Vegetable Oil	Vitamin A	30%	2.5
Wheat Flour	Vitamin B1—Thiamine	0%	0.86
Wheat Flour	Vitamin B2—Riboflavin	0%	0.4945
Wheat Flour	Vitamin B3—Niacin	0%	4.945
Wheat Flour	Vitamin B6—Pyridoxine	0%	0.559
Wheat Flour	Vitamin B12—Cyanocobalamin	15%	0.00129
Wheat Flour	Folate—Folic acid	15%	0.258
Wheat Flour	Iron—Ferrous fumarate	0%	3.44
Wheat Flour	Zinc—Zinc oxide	0%	4

Source: Based on specifications from the 2008 Uganda Food Consumption Survey (Harvey, Rambelson, and Dary 2010)

Results and Discussion

The investigation included 500 females who were neither pregnant nor breastfeeding, drawn from Tanzania's Mbeya area, with an average age of 32.38 years (standard deviation 9.95). **Table 3** provides a detailed summary of the participants' socioeconomic and background profiles. Notably, 12.6% belonged to the 15–19 age group, whereas 15.4% were aged 35–39. Around 70% had completed primary-level schooling, 60.8% engaged in self-employment, 58.3% had between one and four

children, and 18.2% were classified in the lowest category of household wealth. Furthermore, 24.8% of the women were categorized as overweight based on BMI criteria.

Table 3. Socioeconomic and demographic profile of the study participants (n = 500)

Characteristic	Category	n (%)
Age Category (years)	15–19	63 (12.6)
	20–24	77 (15.4)
	25–29	66 (13.2)
	30–34	69 (13.8)
	35–39	77 (15.4)
	40–44	74 (14.8)
	45–49	74 (14.8)
Educational Attainment	No formal schooling	7 (1.4)
	Primary education	315 (63.0)
	Secondary education	108 (21.6)
	Tertiary education	21 (4.2)
	Never attended school	49 (9.8)
Marital Status	Married	196 (39.2)
	Not married	304 (60.8)
Employment Status	Salaried employment	6 (1.2)
	Self-employment	304 (60.8)
	Unemployed	167 (33.4)
	Other forms of work	23 (4.6)
Parity (Live Births)	1–4 births	290 (58.0)
	5–9 births	112 (22.4)
	No live births	98 (19.6)
Household Wealth Quintile	Lowest	91 (18.2)
	Second	93 (18.6)
	Middle	93 (18.6)
	Fourth	93 (18.6)
	Highest	93 (18.6)
Place of Residence	Rural	318 (63.6)
	Urban	182 (36.4)
Council of Residence	Chunya	17 (3.4)
	Kyela	68 (13.6)
	Mbarali	101 (20.2)
	Mbeya City	135 (27.0)
	Mbeya	66 (13.2)
	Rungwe	113 (22.6)
Body Mass Index (kg/m²)	Underweight (<18.5)	24 (4.8)
	Normal (18.5 to <25.0)	254 (50.8)
	Overweight (25.0 to <30.0)	124 (24.8)
	Obese (≥30.0)	98 (19.6)

Table 4 indicates that cereals, cereal-derived products, and dishes prepared from cereals were typically consumed 2–3 times per day by 77.6% of the non-pregnant, non-lactating women of reproductive age. Furthermore, approximately 80% of these women reported no fruit consumption, while 50.4% reported no intake of pulses, nuts, or seeds.

Table 5 presents a detailed inventory of 137 unique food items. Of these, 71 were recorded directly as individual foods, whereas the other 66 represent separate components isolated from composite recipes. Within the recipe category, 87 preparations incorporated oil (including vegetable, sunflower, or palm varieties), 15 household-prepared dishes contained added sugar, 9 commercially produced items included sugar, and 13 recipes featured wheat flour.

Table 4. Distribution of food groups consumed per number of servings among non-pregnant non-lactating women aged 15–49 years in Mbeya.

	Number of Servings							
	Not consumed		Once		2–3		= >4	
Food group	n	%	n	%	n	%	n	%
Cereal, cereal products and cereal-based dishes	0	0.00	15	2.41	484	77.69	124	19.90
Meat, poultry, eggs and fish	296	47.51	197	31.62	125	20.06	5	0.80
Pulses, nuts and seeds	338	54.25	201	32.26	84	13.48	0	0.00
Fruits	499	80.10	92	14.77	29	4.65	3	0.48
Vegetables and vegetable dishes	240	38.52	233	37.40	149	23.92	1	0.16
Sugar and Oil	117	18.78	142	22.79	269	43.18	91	14.61
Unhealthy foods	444	71.27	148	23.76	30	4.82	1	0.16

Table 5. Counts of recipes and individual food items categorized by type

Category / Item Description	Count
Fortification Vehicles and Sugar	
Recipes incorporating oil	87
Recipes incorporating wheat flour	13
Household-prepared recipes with added sugar	15
Commercially produced items containing sugar [a]	9
General Recipes and Single Foods	
Overall number of recipes	113*
Directly reported individual foods	71
Distinct components derived from recipes	66
Grand total of unique food items	137

[a] Includes items such as biscuits, brown bread, bread rolls, white bread, candy, chocolate, ice cream, and soda.

*The recipe total rose after reassembling them using the specific ingredients mentioned by the participants.

Table 6 presents data on the intake of three primary food vehicles employed for large-scale nutrient enrichment. Every participant reported using oil, with intake in the lowest quartile below 36 g and in the upper quartile below 37 g. Intake patterns showed little difference between urban and rural settings, where average (median) amounts were 36.54 g (36.50 g) in urban areas and 36.50 g (36.45 g) in rural areas, respectively.

Results revealed that just over 20% of the participants (110 of 500) reported consuming items containing wheat flour, with lowest-quartile intake under 70.2 g and upper-quartile intake under 209.8 g. A higher proportion of urban women (31%) indicated wheat flour consumption compared to rural women (17%), and urban consumers exhibited markedly greater intake than rural ones at both the lowest quartile (73.4 g versus 57.9 g) and upper quartile (284.5 g versus 142.2 g), Levene test; $P > 0.05$.

Table 6. The consumption of food considered by fortification vehicle and sugar (Homemade and Industrially Made) among the NPNL WRA of each food

Food Item	Residence								Total			
	Rural (N = 319)				Urban (N = 181)				(N = 500)			
	n (%)	Mean (g) Median (g)	Q1 (g)	Q3 (g)	n (%)	Mean (g) Median (g)	Q1 (g)	Q3 (g)	n (%)	Mean (g) Median (g)	Q1 (g)	Q3 (g)
Oil[1]		36.50	35.99	37.02	181(100)	36.54	36.12	37.08	500 (100)	36.51	36.01	37.04

	319 (100)	36.45				36.50				36.47		
Wheat flour[2]	53 (17)	131.29 86.84	57.89	142.23	57(31)	234.07 **142.23*****	73.68	284.45	110 (25)	184.55 110.53	70.23	209.8
Sugar—Home[3]	319 (100)	63.59 51.54	36.91	74.39	181 (100)	60.55 52.42	38.06	69.06	500 (100)	62.49 51.66	37.39	72.7
Sugar—Industrial[4]	28 (9)	27.27 19.89	18.30	37.55	29 (16)	**21.80** * **18.30** **	18.30	24.76	57 (11)	24.49 19.10	18.30	33.0

* *p*-value <0.05 for Levene test centred at the mean (i.e., W0), ** *p*-value <0.05 for Levene test at the median (i.e., W50), *** *p*-value <0.01 for Levene test at the median (i.e., W50)

1. Oil refers to vegetable and palm oils derived from various foods prepared with oil, with intake assessed based on typical consumption patterns.
2. Wheat flour encompasses both plain wheat flour and foods made from it, with intake measured as the actual grams reported by each participant.
3. Sugar—home includes sugar from a variety of homemade (non-industrial) foods, with consumption estimated according to usual intake trends.
4. Sugar—industrial covers sugar obtained from commercially produced items such as biscuits, brown bread, rolls, white bread, candy, chocolate, ice cream, and soft drinks, with intake based on the reported grams consumed by each participant.

Table 7 summarizes the typical daily nutrient intakes for women, showing the median, Q1, and Q3 values according to whether they live in urban or rural areas. The overall median energy consumption was 2,169.9 kcal, with minimal difference between urban and rural residents (2,173 kcal versus 2,169.2 kcal). Urban women tended to have higher Q1 and Q3 values compared to their rural counterparts. The median protein intake was 63.5 g, which was nearly the same across both groups. Notably, the Q3 energy intake surpassed the estimated energy requirements for women in both urban and rural locations. For micronutrients, the Q3 intakes were 6.5 mg for vitamin E, 17.02 mg for iron, and 1.7 g for copper, showing little variation by residence and remaining below the H-AR recommended thresholds.

Table 7. Usual macronutrient and micronutrient intake by place of residence

Nutrient (Measurement)*	H-AR/RDA		Residence						Total		
	Adolescent 15–19 Years Old	Women 20–49 Years Old	Rural (N = 319)			Urban (N = 181)			(N = 500)		
			Mean [Median]	Q1	Q3	Mean [Median]	Q1	Q3	Mean [Median]	Q1	Q3
Energy (kcal)	2200	2100	2171.8 [2169.2]	2069.9	2270.2	2176.7 [2173.5]	2091.2	2255.1	2173.6 [2169.9]	2079.9	2263.5
Vitamin A (µg [RAE])	490	490	1128.6 [733.4]	324.3	1380.3	1147.1 [804.2]	343.1	1505.5	1135.3 [772.3]	330.1	1430.3
Protein (g)	48	56	63.6 [63.5]	59.8	67.2	63.8 [63.7]	60.6	66.7	63.7 [63.5]	60.2	67.0
Thiamine (mg)	0.9	0.9	1.1 [1.3]	0.7	1.4	1.1 [1.3]	0.7	1.4	1.1 [1.3]	0.7	1.4
Niacin (mg)	11	11	10.4 [12.4]	7.3	13.6	10.4 [12.5]	6.7	13.6	10.4 [12.4]	7.3	13.6
Riboflavin (mg)	1.4	1.3	1.7 [1.2]	0.8	2.7	1.7 [1.2]	0.8	2.7	1.7 [1.2]	0.8	2.7
Vitamin B6 (mg)	1.3	1.3	1.2 [1.5]	1.0	1.6	1.2 [1.5]	1.0	1.6	1.2 [1.5]	1.0	1.6
Vitamin B12 (µg)	2	2	2.1 [1.4]	1.3	1.5	2.5 [1.4]	1.3	2.2	2.2 [1.4]	1.3	1.5
Vitamin E (mg)	12	12	7.7 [6.2]	5.9	6.5	7.8 [6.2]	5.9	6.5	7.7 [6.2]	5.9	6.5
Vitamin C (mg)	75	80	78.7 [102.8]	46.6	111.1	78.7 [105.2]	42.5	110.9	78.7 [103.9]	44.7	111.0
Copper (g)	0.685	0.7	1.7	1.6	1.7	1.7	1.6	1.7	1.7	1.6	1.7

			[1.7]			[1.6]			[1.7]		
Iron (mg)	22.4	22.4	20.5 [16.0]	15.4	17.2	21.0 [16.1]	15.5	16.9	20.7 [16.1]	15.4	17.0
Folate (µg)	250	250	328.5 [397.8]	209.7	419.6	328.7 [401.6]	208.2	422.1	328.6 [398.2]	209.6	421.0
Zinc (mg)	10.2	10.2	9.2 [9.6]	9.2	9.9	9.2 [9.7]	9.2	10.0	9.2 [9.6]	9.2	10.0

* Nutrient intake was estimated using the TFCT, without accounting for the contribution of fortified foods.

In this investigation, **Table 8** displays the proportion of study participants exhibiting inadequate consumption of various nutrients. The rates of insufficiency varied widely, from just 2.6% for protein up to 90.6 percent for zinc. The most pronounced deficiencies were observed for zinc (90.6 percent), vitamin E (89.0 percent), iron (80.0 percent), vitamin B12 (78.8 percent), and riboflavin (53.0 percent). Roughly one-third of the female participants fell short in meeting requirements for energy, folate, and thiamine. Furthermore, approximately one-quarter showed insufficient levels of vitamin A, niacin, vitamin C, and vitamin B6.

To highlight the extent of these dietary shortfalls among the women, we determined both the absolute deficits and their proportions relative to the Harmonized Average Requirement (H-AR) specifically for the lowest intake quintile (Q1). In Q1, the absolute shortfalls spanned from 0.2 mg (thiamine) to 70.1 kcal (energy). The largest proportional deficits in Q1 were seen for vitamin E (representing 50.7% of H-AR, equivalent to 6.1 mg), vitamin C (42.3 percent of H-AR, or 32.8 mg), and riboflavin (40.9 percent of H-AR, or 0.6 mg). Proportional gaps ranging from 30% to 40% of H-AR applied to niacin, vitamin B12, and iron. The shortfall for vitamin A amounted to 159.9 µg in absolute terms, corresponding to 32.6 percent of H-AR. For vitamin B6, the absolute deficit was 0.3 mg, equating to 26.5% of H-AR. Folate showed an absolute gap of 40.5 µg, or 16.2% of H-AR. Lastly, zinc had an absolute shortfall of 1 mg, comprising 9.8% of H-AR.

Table 8. Distribution of habitual nutrient consumption, proportion of participants with intake falling short of the Harmonized Average Requirement (H-AR), and extent of nutrient deficits in the lowest quintile (Q1) (Total sample N = 500; Subsample for inadequacy prevalence n = 120).

Nutrient* (Unit)	Median Intake	Q3 Intake	Q1 Intake	Absolute Deficit in Q1±	Proportion with Inadequate Intake (% < H-AR)	Proportional Deficit in Q1 (% of H-AR)ǂ
Energy (kcal)	2169.88	2263.54	2079.90	70.1	34.4	3.3
Protein (g)	63.52	66.99	60.21	-	2.6	-
Vitamin A (µg RAE)	772.26	1430.32	330.12	159.9	37.0	32.6
Thiamine (mg)	1.23	1.41	0.70	0.2	34.8	22.8
Riboflavin (mg)	1.23	2.70	0.79	0.6	53.0	41.9
Niacin (mg)	12.48	13.59	7.26	3.7	44.4	34.0
Vitamin B6 (mg)	1.47	1.59	0.96	0.3	45.2	26.5
Vitamin B12 (µg)	1.37	1.53	1.29	0.7	78.8	35.5
Vitamin C (mg)	103.93	111.00	44.72	32.8	45.6	42.3
Vitamin E (mg)	6.18	6.51	5.91	6.1	89.0	50.7
Copper (mg)	1.65	1.73	1.58	-	0.0	-
Folate (µg)	398.18	420.99	209.55	40.5	32.6	16.2
Iron (mg)	16.05	17.02	15.39	7.0	80.0	31.3
Zinc (mg)	9.63	9.96	9.21	1.0	90.6	9.8

* Nutrient consumption levels were assessed utilizing the Thai Food Composition Table (TFCT), without accounting for contributions from fortified products.

± Absolute shortfall determined by subtracting the actual intake value at Q1 from the H-AR (or RDA in the case of energy).

ǂ Proportional shortfall computed as the absolute shortfall divided by the H-AR (or RDA) and expressed as a percentage.

Table 9 presents a comparison of median habitual nutrient intakes derived from the Thai Food Composition Table (TFCT) and the Updated Food Composition Table (UFCT). Levene's test was applied to assess differences in median usual intake for each nutrient.

When the analysis was restricted to non-fortified foods (NFF) or dietary sources excluding fortification, significant differences ($P < 0.05$) were observed between the TFCT and UFCT in the median habitual intakes of energy, vitamin A, riboflavin, niacin, vitamin B6, vitamin C, and folate.

In contrast, when fortified foods were included in the assessment, significant differences ($P < 0.05$) between the two composition tables were found only for vitamin A (as retinol activity equivalents, RAE), vitamin C, and iron. For all remaining nutrients, no statistically significant differences were detected in median usual intakes between the TFCT and UFCT.

Table 9. Comparison of median usual nutrient intakes estimated using non-fortified foods only and using foods with fortification, based on the Tanzania Food Composition Table (TFCT) and the Updated Food Composition Table (UFCT) (N = 500).

Nutrient (Unit)	Non-Fortified Foods		Fortified Foods	
	UFCT Median (IQR)	TFCT Median (IQR)	UFCT Median (IQR)	TFCT Median (IQR)
Energy (kcal)	2238.55* (193.22)	2169.88 (183.98)	2265.76 (232.12)	2260.96 (243.11)
Protein (g)	63.90 (7.09)	63.52 (6.79)	66.28 (7.83)	66.26 (7.76)
Vitamin A (µg RAE)	1499.78[a] (138.55)	772.26 (1102.1)	2541.06* (1871.1)	1848.91 (155.70)
Thiamine (mg)	1.14 (0.64)	1.23 (0.72)	1.23 (0.75)	1.25 (0.66)
Riboflavin (mg)	1.08[a] (0.07)	1.23 (1.91)	1.16 (0.07)	1.23 (1.91)
Niacin (mg)	13.09[a] (6.73)	12.48 (6.35)	12.80 (6.90)	12.68 (6.96)
Vitamin B6 (mg)	1.90[a] (0.95)	1.47 (0.64)	1.54 (0.91)	1.49 (0.98)
Vitamin B12 (µg)	1.73 (0.32)	1.37 (0.24)	2.63 (0.34)	2.63 (0.34)
Vitamin C (mg)	78.32[a] (56.94)	103.93 (66.37)	78.32* (61.98)	90.40 (60.20)
Vitamin E (mg) †	—	6.18 (0.60)	—	6.18 (0.60)
Copper (g) †	—	1.65 (0.15)	—	1.65 (0.15)
Folate (µg)	411.79[a] (214.96)	398.18 (211.60)	493.81 (287.40)	493.46 (288.53)
Iron (mg)	16.58 (1.96)	16.05 (1.64)	19.82* (4.30)	17.55 (2.70)
Zinc (mg)	9.68 (1.12)	9.63 (0.76)	9.69 (1.13)	9.64 (0.777)

† Vitamin E and copper were not available in the Uganda FCT

a p-value <0.05 non-fortified TFCT vs. UFCT; and b p-value <0.05 fortified TFCT vs. UFCT. The study uses p-values computed from the Levene's test using the median.

Table 10 illustrates the proportion of individuals with insufficient vitamin A intake across three distinct scenarios: (1) relying solely on natural dietary sources (excluding fortified foods) based on the TFCT; (2) incorporating fortified oil alongside the regular diet, using the TFCT; and (3) applying the UFCT overall.

In the scenario considering diet alone, the median vitamin A intake was 772.3 µg, with approximately 37% of the population exhibiting inadequate intake, as indicated in **Tables 7 and 8**. The addition of fortified oil under the TFCT raised the median vitamin A intake to 1848.9 µg, while the UFCT yielded a median of 2541.1 µg. Consequently, the prevalence of inadequate vitamin A intake dropped substantially to 7.4 percent and 5.6 percent in these two fortified scenarios, respectively. These results underscore the significant positive impact of vitamin A-fortified oil consumption on reducing deficiency rates.

Table 10. Habitual vitamin A consumption and estimated proportion of inadequate intake under fortification scenarios (Levene Test), predicted Vitamin A intake (N = 500)

Predicted Scenario	Median Intake (µg)	Prevalence of Inadequacy (%)
Diet alone (non-fortified TFCT)	772.26[a,b]	37%[a,b]
Diet plus fortified oil (fortified UFCT)	2541.07	5.6%
Diet plus fortified oil (fortified TFCT)	1848.91	7.4%

[a] $p < 0.001$ for comparison between non-fortified TFCT and fortified TFCT [b] $p < 0.001$ for comparison between non-fortified TFCT and fortified UFCT

Table 11 illustrates the notable decline in insufficient consumption of vitamin B12 and folate resulting from

wheat flour fortification according to the Tanzania Food and Drugs Authority (TFDA) standards, as assessed via the Levene test. Prior to fortification, the median habitual folate intake stood at 398.2 µg. Following fortification, this rose to 493.5 µg—a change that proved statistically significant ($p < 0.01$)—while the proportion of inadequate intake fell from 32.6% to 25.8%. In a similar pattern, median habitual vitamin B12 intake climbed from 1.4 µg to 2.6 µg, leading to a marked drop in inadequacy prevalence from 78.8% to 0.4%, likewise significant at $p < 0.01$. For zinc, median habitual intake improved from 9.63 mg to 10.5 mg, yielding a considerable reduction in the rate of inadequate zinc intake from 90.6% to 27.8%. It should be highlighted that the TFDA-mandated wheat flour fortification program in Tanzania excludes thiamine, riboflavin, niacin, and vitamin B6, with mild inadequacies for each of these nutrients persisting in the range of approximately 30–40%.

Table 11. Habitual micronutrient consumption and estimated proportion of inadequate intake under fortification scenarios (Levene Test)

Nutrient Added	NFF TFCT (N = 500)		FF TFCT (N = 500)	
	Inadequacy (%)	Median	Inadequacy (%)	Median
Thiamine (mg)	34.8%	1.23	34.8%	1.25
Riboflavin (mg)	53.0%	1.23	53.0%	1.23
Niacin (mg)	44.4%	12.48	44.4%	12.68
Vitamin B6 (mg)	45.2%	1.47	45.2%	1.49
Vitamin B12 (µg)	78.8%	1.37	0.4%[a]	2.63[a]
Folate (µg)	32.6%	398.18	25.8%[a]	493.46[a]
Iron (mg)	80.0%	16.05	76.2%	17.55
Zinc (mg)	90.6%	9.63	27.8%[a]	10.57[a]

[a] $p < 0.001$ for comparison between non-fortified flour TFCT (NFF TFCT) and fortified flour TFCT (FF TFCT)

The research reveals elevated rates of insufficient micronutrient consumption, including zinc, vitamin E, iron, vitamin B12, and riboflavin, in non-pregnant, non-lactating women of reproductive age (NPNL WRA) residing in Tanzania's Mbeya Region. These deficiencies stem primarily from reduced intake of animal products like meat, dairy, fish, and poultry, as well as whole grains and dark green leafy vegetables [24–27]. Existing research indicates that incorporating foods high in vitamin C—such as oranges, papaya, cabbage, and green leafy vegetables—enhances absorption of non-heme iron from sources like nuts, beans, or amaranth leaves, which are commonly eaten by NPNL WRA in Mbeya [28].

Data collection occurred in the dry season, where seasonal fluctuations may influence 24-hour recall results. Availability of certain fruits and vegetables varies by season, potentially introducing bias in estimates of typical dietary patterns and leading to imprecise nutrient assessments [22, 23]. Nonetheless, the NCI method for estimating usual intake addresses this by accounting for variability in daily consumption and seasonal food access [22, 23].

Results from this investigation correspond with international research. For instance, Goh *et al*. (2023) observed deficient consumption of key micronutrients like iron, zinc, and vitamin B12 in NPNL WRA [26]. Otunchieva *et al*. (2022) similarly noted micronutrient shortfalls among women of reproductive age in lower-income nations [16]. Sharma *et al*. (2020) further reported that many women globally fall short of recommended iron levels [18]. In southeastern Nigeria, Onyeji and Sanusi (2022) found limited micronutrient consumption in women of reproductive age, with urban residents showing marginally better energy and protein levels compared to rural ones [15]. These patterns echo findings from a Vietnamese study by Nguyen *et al*. (2013) involving women of reproductive age [14].

Existing studies stress the value of assessing nutrient shortfalls in the lowest quartile (Q1), as this represents the deficit most amenable to targeted interventions [29]. The present work examines comprehensive strategies to tackle low consumption of nutrients, particularly vitamin E, iron, vitamin B12, riboflavin, and vitamin C. Results indicate modest zinc deficiency (9.8% above the H-AR threshold), suggesting that fortification programs and better eating habits could substantially lower the elevated inadequacy rate (91.2%) [29].

Participants in the NPNL WRA category frequently included vitamin A sources like carrots, orange-fleshed sweet potatoes, and leafy greens such as pumpkin leaves, spinach, and amaranth. Yet vitamin A inadequacy persists as an issue, supporting the potential benefits of vitamin A fortification in foods [29–31].

Every respondent reported using oil in cooking, with comparable amounts across urban and rural settings, given its routine role in meal preparation. Common types were vegetable or palm oil derived from various sources. Rural women showed greater sugar consumption than urban counterparts, encompassing added sugars in prepared items, beverages, homemade dishes, fruit juices, and concentrates [32–36].

The investigation evaluated intake of fortified items like edible oil and wheat flour. Earlier data from 2015 indicated 22 g/day for oil and 162 g/day for wheat flour among women of reproductive age [7], though calculated differently from the current approach. Coverage and consumption of wheat flour fortification were limited, with higher average amounts among urban consumers.

Intake of fortified oil and wheat flour was associated with higher levels of vitamins A and B12, as well as zinc, and lower rates of deficiency relative to unfortified versions. During data processing, tools were created, including detailed recipe compositions and conversions from local units to metrics. These resources could enhance future standardized 24-hour recall tools in Tanzania, such as multi-pass surveys, photographic aids, and digital templates.

Despite efforts to minimize biases, the study faces constraints in data gathering and processing. Bioavailability factors like phytate were not measured, nor were specific brands of fortified oil or flour identified. Simulations used mandated fortificant levels rather than actual content to project effects on vitamin A deficiency (via oil) and shortfalls in vitamin B12, folate, iron, and zinc (via wheat flour). Persistent high inadequacies in thiamine, riboflavin, niacin, and vitamin B6 were linked to their absence in wheat flour fortification, within recommended fortificant ranges.

Inaccuracies in the Tanzania Food Composition Table (TFCT) nutrient values were identified and corrected, including energy recalculations via the 4:4:9:2 method (for protein, carbohydrates, fat, and fiber) and reviews of pro-vitamin A conversion factors. Comparisons with the USDA Food Composition Table (UFCT) validated most inadequacy results, though vitamin E and copper could not be contrasted due to missing UFCT data.

Results apply solely to NPNL WRA in Mbeya, limiting broader application to other groups or regions. Challenges arose in handling zero or missing values for riboflavin and vitamin B12 in the episodic SAS macro, which assumes random missingness for infrequently consumed items. Multiple scenarios were tested, initially adjusting zeros to half the minimum and using 100 bootstraps, yielding unrealistic 100% adequacy or inadequacy. Final adjustments retained zeros, increased bootstraps to 200, and scaled weights by 100, producing more plausible estimates. Caution is advised in interpreting these, as data may deviate from random patterns, risking biased estimates.

Conclusion

This investigation demonstrates widespread insufficient micronutrient consumption in NPNL WRA from Tanzania's Mbeya Region, largely due to limited intake of meat, dairy, fish, poultry, whole grains, and dark green leafy vegetables. Priority should focus on improving access to vitamin E, iron, and vitamin B12, then riboflavin and vitamin C, given their inadequacy rates. Nutrient gaps in the lowest quartile remain below 50% of the H-AR for these, and under 35% for other B vitamins (thiamine, niacin, vitamin B6, folate). The minor zinc gap suggests straightforward improvements via fortification or diet. Oil consumption patterns position it as an effective vehicle for reducing deficiencies in vitamins A, D, and E. Wheat flour fortification, however, offers restricted benefits due to low coverage among NPNL WRA in Mbeya. Additional validation of episodic consumption models is required to strengthen usual intake estimates, especially for riboflavin and vitamin B12, in this Tanzanian context.

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