Gender and Age Differences in Meal Structures, Food Away from Home, Chrono-Nutrition, and Nutrition Intakes among Adults and Children in Tanzania Using a Newly Developed Tablet-Based 24-Hour Recall Tool

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ABSTRACT

Background: In many regions of the world, little is known about meal structures, meal patterns, and nutrient intake because the collection of quantitative dietary intake is expensive and labor-intensive.

Objectives: We describe the development and field feasibility of a tablet-based Tanzania 24-h recall tool (TZ-24hr-DR) and dietary intakes collected from adults and children in rural and urban settings.

Methods: Using the Tanzanian food-composition table, the TZ-24hr-DR tool was developed on an Android platform using the Open Data Kit. The module provides food lists, meal lists, ingredient lists, quantity and amount consumed, breastfeeding frequency, and a recipe feature. Similar to the USDA Automated Multiple Pass Method, this TZ-24hr-DR contains review features such as time in-between meals, a summary of meals, and portion sizes.

Results: Dietary intake using TZ-24hr-DR was collected among 1) 845 children 0–18 mo of age enrolled in the Engaging Fathers for Effective Child Nutrition and Development in Tanzania (EFFECTS) trial (ClinicalTrials.gov identifier: NCT03759821) in Mara, Tanzania, and 2) 312 adult families from the Diet, Environment, and Choices of positive living (DECIDE) observational study in peri-urban Dar es Salaam. Interviewers were trained on paper-based methods with food models and tablet-based collection. Conversion to nutrient intake was readily linked and accessible, enabling rapid review and analysis. Overall, 2158 and 8197 dietary meal records were collected from the DECIDE study and EFFECTS trial, respectively. Among adults, 63% of men and 92% of women reported eating at home, and there were differences in protein, fat, and zinc. Food consumed outside the home typically occurs for the first 2 meals. Children’s intake of nutrients increased with age; however, median micronutrient intakes for calcium, iron, zinc, and vitamin A remained below recommended nutrient intakes.

Conclusions: The TZ-24hr-DR is a field- and user-friendly tool that can collect large samples of dietary intakes. Further validation is needed. The tool is available freely for research purposes and can be further adapted to other contexts in East Africa.

Keywords: tablet, open data kit, dietary data, nutrient intakes, Tanzania, diets, children, adults

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Manuscript received October 24, 2021. Initial review completed January 18, 2022. Revision accepted January 26, 2022. Published online February 8, 2022.

This work was supported, in whole or in part, by the Bill & Melinda Gates Foundation [Grant Number ID: OPP1110043]. Under the grant conditions of the Foundation, a Creative Commons Attribution 4.0 Generic License has already been assigned to the Author Accepted Manuscript version that might arise from this submission.

This paper was presented at the American Society of Nutrition (ASN) in Baltimore, MD, USA (2019).

The Diet, Environment, and Choices of positive living (DECIDE): Evaluating personal and external food environment influences on diets among PLHIV (persons living with HIV) and families in Dar es Salaam, Tanzania, study is funded through the Drivers of Food Choice Grants Program by the Bill and Melinda Gates Foundation (ID: OPP1110043) and the Foreign, Commonwealth, and Development Office (FCDO). The EFFECTS trial is funded by the Eleanor J Crook Foundation and the Conrad N Hilton Foundation.

Author disclosures: The authors report no conflicts of interest. The funders did not play a role in study design, data collection, data analysis, data interpretation, or data writing.

Supplemental Figures 1 and 2, Supplemental Report 1, and Supplemental Table 1, and are available from the “Supplementary data” link in the online posting of the article and from the same link in the online table of contents at https://academic.oup.com/cdn/.

The DECIDE study is a collaborative project funded by Purdue University, University of Chicago at Illinois, Muhimbili University, and Africa Academy of Public Health.

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Abbreviations used: DECIDE, Diet, Environment, and Choices of positive living; EFFECTS, Engaging Fathers for Effective Child Nutrition and Development in Tanzania; FCT, food-composition table; FFQ, food-frequency questionnaire; IRB, Institutional Review Board; LMIC, low- and middle-income country; ODK, Open Data Kit; PLHIV, persons living with HIV; RNI, Recommended Nutrient Intake; TZ-24hr-DR, Tanzania 24-h recall tool.
Introduction

Globally, dietary risk factors account for one-quarter of all deaths (1). In addition, there is an increasing burden from over- and undernutrition due to drastic shifts in food environments, consumption patterns, migration, and demographic transition in low- and middle-income countries (LMICs) (2–8). However, little is known about dietary patterns in LMICs, particularly meal structures, the timing and location of meal patterns, and nutrient intakes (9). To address the shifting nutrition profiles, public health programs require data capturing dietary intake and consumption patterns of individuals and populations that are easy to collect and reliable, especially assessing dietary data over time (9). However, collecting these data using quantitative dietary intake, particularly the 24-h dietary methodology, is expensive and labor-intensive for 2 main reasons: first, collecting dietary recalls requires interviewing and probing skillsets, quantitative estimation, and general knowledge of recipes and cooking practices in the local context (10), and second, the processing of dietary data to estimate portions consumed and nutrient intakes requires up-to-date food-composition databases and often requires staff with nutrition training.

These 2 labor-intensive steps have primarily reduced the availability of quantitative dietary data collection in LMICs. The availability and use of digital tools such as tablets or smartphones combined with the availability and use of open-source software such as Open Data Kit (ODK) have enabled adopting the collection of dietary recalls in LMICs. We have identified 7 digital dietary recall tools that have been used in LMICs so far, including the tool from this current paper (11–16). Here, we focus on tablet-based rather than computer or online self-reported tools for the feasibility of data collection in the field among vulnerable populations who may not have the education and familiarity for self-reported instruments. Out of these 7 identified tools, 3 tools are built using an open-source platform, 2 include recipe features, and all have used aids, whether food models or utensils or photographs, in the recall. More recently, the International Dietary Data Expansion Project has established 9 criteria for evaluating whether the 24-h recall digital dietary data collection is optimal for scale-up and use in nutrition programs (17). These criteria include use of multiple-pass interview methods, being interview administered, having photo aids for portion-size estimation, links to a food-composition database, ability to use both paper and electronic data collection, field feasibility (running offline), adaptability across different contexts, scalable for national surveys, ease of use, and finally, low cost to adopt (17). All the identified 7 dietary assessment tools use multiple-pass methods, offline data collection features, and are interview administered. Only half of the tools have pictorial aids, while one-third were tested across different contexts. More importantly, only 3 tools are available freely (either upon request or available online).

The main purpose of this paper is to describe the development and field feasibility of a tablet-based Tanzania 24-h dietary recall tool (TZ-24hr-DR) and assess dietary intakes collected using the TZ-24hr-DR tool from adults and children in urban and rural Tanzanian settings. Finally, dietary intakes collected from this tool are compared with other relevant studies conducted in the same settings (12). We have added several innovative features, such as the summary of meals, portion size, timing of dietary intakes, ability to add recipes, and location of meal consumption, to reduce data collection and estimation error. Here we provide information on meal structures, chrono-nutrition, meals away from home, and nutrient intakes in 2 rapidly changing food environment settings in Tanzania.

Methods

Study setting

The TZ-24hr-DR was used in 2 study populations (adults and children) in Tanzania. First, this tool was used in an observational cohort called the Diet, Environment, and Choices of positive living (DECIDE) study, which evaluates personal and external food environments among adult people living with HIV (PLHIV) and an adult family member of theirs (18). Data from the first wave of data collection are presented here. The DECIDE cohort is set in the Dar es Salaam Urban Cohort Study, which is a low-income community right outside of the commercial capital of Tanzania (19). Second, TZ-24hr-DR was used in a baseline evaluation of Engaging Fathers for Effective Child Nutrition and Development in Tanzania Study (EFFECTS; ClinicalTrials.gov Identifier: NCT03759821), a cluster-randomized trial among rural agrarian families with children 0–18 mo of age in the northern Mara region, Tanzania. The EFFECTS trial tested the impact of father engagement (in addition to mothers) to improve child nutrition and development. The National Institute for Medical Research in Tanzania provided ethical approvals for both Tanzanian studies. In addition, the DECIDE study had Institutional Review Board (IRB) approvals from Purdue University, and the EFFECTS study had IRB approvals from Harvard University, through which Purdue has a reliance agreement. Informed consent was provided by adults enrolled in the DECIDE study and by the caregivers (both parents) for collecting dietary data among children enrolled in the EFFECTS study. Participants did not receive any monetary compensation for the collection of data.

Enrollment of the study participants

Enrollment in the DECIDE study has been described elsewhere (18). Briefly, 2600 participants were screened at community clinics in 2019 and 396 were eligible to participate in the DECIDE study. PLHIV participants were eligible to participate if they were above 18 y of age, provided informed consent to participate in both rounds of the study, and lived in the study area. The adult family member also provided informed consent. Out of 396 eligible participants, 70 were not available for interviews or moved away before the first round of data collection. Out of the remaining 326 participants, 14 had missing 24-h recalls, so 312 PLHIV participants, and their family members when available, were included from the DECIDE study. Enrollment in the EFFECTS study has also been described elsewhere (20). Briefly, households from 80 villages in 2 districts in the Mara region of Tanzania were enrolled in a cluster-randomized controlled trial in 2019. Households were eligible to participate if they had a child aged 0–18 mo at enrollment, both parents consented to participate in interventions (except for those in control arms) and 3 annual evaluations, the household intended to stay in the study setting for the duration of the study, and the father would be present in the household for at least 10 mo of the year. Overall, 960 households were enrolled; however, 30 households were lost to follow-up before the first round of data collection and were replaced using the same eligibility criteria. For these analyses, we included the 88% of children who
had consumed non–breast-milk foods in the previous day at the time of baseline data collection.

Development of the TZ-24hr-DR tool
Using the Tanzanian food-composition table (FCT), the TZ-24hr-DR tool was developed on an Android platform using ODK (20, 21). This development entailed revising a paper version of the 24-h recall questionnaire into a standard Excel form called the XLSForm, which was then converted into an ODK format called the XForm. The XLSForm included food item files from Tanzania FCT and incorporated quality, flow control, and skip patterns as the interviewer selected the list of menus nested under each choice. Flow control refers to the order through which the interviewer recorded information, and skip pattern refers to a sequence of choices based on previous answers. For example, the selection of cereal food group will produce a list of ingredients and meals with cereal as an ingredient from the Tanzanian FCT, which includes a list of 31 food items (such as infant cereal, sorghum porridge, etc.) (20). The flow control and skip patterns mimicked paper-based dietary recall methods and were iteratively optimized based on feedback from the nutritionists and interviewers, thus improving the overall quality of data collection.

The training was conducted in 2 phases among interviewers who had completed high school education and had experience conducting public health surveys in these communities. First, interviewers were trained using paper-based methods to become acquainted with the concept of a 24-h dietary recall interview form. Then, they were oriented on interviewing techniques, probing, free listing activities, and meals consumed in the previous 24 h. After that, detailed information on ingredients, portion sizes, and serving sizes was collected for each meal. The second phase of the training included an orientation on collecting 24-h recall using a tablet. These training sessions on tablet data collection were done by a facilitator (author DM) and a nutritionist (authors SN, RA, and CP) and used examples to show how to use the tool. Later, fieldworkers practiced among themselves and did a short pilot training in the community before deployment.

Fieldworkers were trained with 3 interview aids: serving size utensils, food lists, and a notebook for free listing activities and meals. Reference serving size aids included 7 utensils: bowl, cup, tumbler, plate, tablespoon, teaspoon, and saucer (see Supplemental Figure 1). Since most fieldworkers were not familiar with how meals were categorized under food groups, the data-collection process was slow initially. This helped us to correct for the appropriate FCT code. For example, there are 2 kinds of samosas, one with meat and one with potatoes, and they vary distinctly in terms of nutrients and energy. In part D, we asked the participant if they knew the recipe of the meals. The recipe feature allowed the interviewer to collect detailed information such as cooked and uncooked weight and a free-text feature for notes on the cooking method. There was a free-text option called “other comments” for each meal where the interviewer was instructed to collect additional information on feeding, brand, and parts of the meal consumed. Some examples include siblings feeding the baby even though the mother prepared the meal or consuming only the broth, not the meat portion of fish stew.

At the end of each meal-recipe (part B to D) loop, interviewers were asked if they wanted to add a meal or finish the survey for review. If the survey is completed, the TZ-24hr-DR provides a summary of all the meals consumed (part E). This summary included timing of meals, review of meals, and portion size consumed in the previous day for the interviewer to review any significant time gaps, implausible portion sizes (e.g., 8 cups of cooked rice for a 13-mo child), and meals (e.g., strawberry juice in remote Mara region is not possible because strawberries are not available here).

Other dietary information, such as nutritional supplement use, breastfeeding frequency, and family diets (e.g., DECIDE study collected data from 2 members of the same household), can also be captured with this tool. Breastfeeding was also entered as a meal at each specific time the mother fed the child. Additional quality checks were included on breastfeeding—for example, the breastfeeding frequency had to match the number of breastfeeding “meals” entered. For example, if the interviewer entered 6 for breastfeeding frequency at the beginning of the survey, they also must enter 6 breastfeeding meals with timing and location.

Phase 2: real-time processing of dietary recalls
Data collection for the first round of the DECIDE study among 312 PL-HIV adults and 214 family members of PLHIV was conducted between February and June 2019. We report dietary intakes from the 312 PL-HIV’s dietary intake (family members’ dietary intakes are not included here). The baseline evaluation for the EFFECTS trial was conducted from December 2018 to May 2019. In the EFFECTS trial, dietary recalls from children were collected from the primary caregiver responsible for preparing food and feeding the child (mother). Primary caregivers, usually mothers, were queried for the dietary recall for her child enrolled in the EFFECTS trial. Since the data were collected and transmitted readily to the server with the availability of the 3G mobile network, we were able to do real-time processing and create daily reports to review
Phase 1: Data collection

Part A: Record Demographics, Individual ID, Consent, Name, Date
Characterization of yesterday (normal day, festival, fasting, other). Nutrition supplement use and type
[Child only] Breastfeeding frequency (child dietary intakes)
[Child only] Did the child consume any foods besides breast milk?

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**FIGURE 1** Flow of TZ-24hr-DR tool from demographics, food consumption, ingredient information, and recipe information. Asterisks indicate there were many choices. TZ-24hr-DR, Tanzania 24-h recall tool.

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Phase 2: Real-time processing with data collection

Phase 3: Post-data collection: processing nutrient intake and unknown meals, and developing new recipes

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any issues with data collection. These included missing forms, the timing of first meals, frequently consumed meals by meal order (breakfast, lunch, dinner, and any other meals in-between including snacks and beverages), breastfeeding frequency (sample report from the EFFICITS trial is included in Supplemental Report 1), and creation of dietary profiles for everyone (Figure 2). Any issues, such as implausible values or timings or food items, raised in the automated report were relayed to the on-site nutritionist and interviewers.

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**Phase 3: post-data collection: processing nutrient intakes**

Each dietary recall from an individual was collected in 2 datasets, which were sent to the servers on the same day: 1) a demographics dataset that had 1 record per participant per day, which included information collected in part A of Figure 1, and 2) a secondary meal dataset, which had multiple records of meals per participant per day (part B to D). Each meal record was easily linked to the Tanzanian FCT because it used the same code. Users can also enter unknown meals by code “9999,” along with the description of the meals. These unknown meals...
were manually checked for any corresponding codes in the Kenyan FCT since they were not found in the Tanzanian (22). If a similar code was not found in the Tanzanian FCT or the Kenyan FCT, a recipe using the user-provided input on ingredients and/or recipe instruction was created and assigned to each specific unknown meal (code: “8888”; see next section on unknown/recipe analysis). Then, these changes were made in Stata files to be reviewed additionally by trained nutritionists for appropriate assignments. After all the codes were
FoodData Central (23). Nutrient retention factors for locally prepared
meals (including breastfeeding) under 2 years of age were collected from the EFFECTS trial. For DECIDE participants, the median age was 41 years, and the median education was seventh grade. One-third of the DECIDE households were food secure, while only 11% of the households were food secure in the EFFECTS trial. In the EFFECTS trial, most of the children aged 11 months (82%) had breast milk in their diets. Wood was the common cooking fuel in the rural EFFECTS trial (95%), while charcoal was common in the urban DECIDE study (74%). We present results by gender for adults (DECIDE study) and by age groups for children (EFFECTS trial, when possible) because adults’ diets vary notably by gender, while child diets vary as they age in their early childhood years.

A total of 2158 and 8197 dietary meal records were collected from the DECIDE study and EFFECTS trial, respectively. In Tables 3 and 4, descriptions of meals and the location of food consumption from both studies are shown. DECIDE participants had a median of 7 meal records (IQR: 5, 8) and 3 meals/day (IQR: 3, 4). Sixty-three percent of the male participants reported eating meals at home compared with 92% of women. Less than 1% of adult PLHIV participants reported supplement use. Children’s mean frequency decreased as they aged, from consuming 9 meals (including breastfeeding) under 12 months of age to 6 meals by the time they reached 19–24 months of age. By 19–24 months, only 39% of the mothers reported breastfeeding on the previous day.

Tables 5 and 6 summarize the most frequently consumed foods by adults and children in the DECIDE and EFFECTS studies, disaggregated by gender and age groups, respectively. The most consumed food items across both studies were stiif maize porridge, tea, rice boiled in water with oil, beans, beef relish, and green leafy relish. In the DECIDE study, the commonly consumed meat items were fish and beef relish (and beef broth for men). Ultra-processed foods such as African donuts (made of highly processed food such as flour, sugar, oil) and carbonated drinks were also frequently consumed, and these were often consumed outside the house. The most consumed foods outside of the home were carbonated sodas, chapati with oil, rice boiled in oil, tea, and fried potato chips. In the EFFECTS trial, meal consumption patterns by age group of

TABLE 1 Background characteristics of the DECIDE study (by gender)\(^1\)

|                          | Male (n = 77) | Female (n = 235) | Total (n = 312) |
|--------------------------|--------------|-----------------|-----------------|
| Age, y                   | 44 (37, 50)  | 40 (32, 47)     | 41 (33, 48)     |
| Are you the head of the household? (%) | 72.7 (56)   | 37.9 (89)       | 46.5 (145)      |
| Participant education (%)| Up to seventh grade | 75.3 (58)     | 77.4 (182)      | 76.9 (240)    |
|                         | Above seventh grade | 24.7 (19)     | 22.6 (53)       | 23.1 (72)     |
| What is the main fuel used for cooking? (%) | Gas (industrial) | 15.6 (12)      | 13.6 (32)       | 14.1 (44)     |
|                         | Paraffin     | 11.7 (9)        | 2.1 (5)         | 4.5 (14)      |
|                         | Charcoal     | 68.8 (53)       | 75.3 (177)      | 73.7 (230)    |
|                         | Firewood     | 3.9 (3)         | 8.9 (21)        | 7.7 (24)      |
|                         | BML, kg/m²   | 21.9 (20.2, 24.9) | 23.7 (20.7, 28.8) | 23.2 (20.5, 27.6) |
| Household Food Insecurity Access (%) | Food secure | 31.2 (24)       | 27.2 (64)       | 28.2 (88)     |
|                         | Mildly food insecure | 5.2 (4)        | 9.8 (23)        | 8.7 (27)      |
|                         | Moderate food insecurity | 27.3 (21)    | 29.8 (70)       | 29.2 (91)     |
|                         | Severe food insecurity | 36.4 (28)     | 33.2 (78)       | 34.0 (106)    |

\(^1\)Values are n (%) or median (IQR). DECIDE, Diet, Environment, and Choices of positive living; PLHIV, persons living with HIV.

Results

Tables 1 and 2 summarize the demographic characteristics of both study populations. From the DECIDE study, dietary data on 312 adult PLHIV (75.3% female) participants living in peri-urban Dar es Salaam were collected, while data on 845 children (49.7% female) under 2 years of age were collected from the EFFECTS trial. For DECIDE participants, the median age was 41 years, and the median education was seventh grade. One-third of the DECIDE households were food secure, while only 11% of the households were food secure in the EFFECTS trial. In the EFFECTS trial, most of the children aged 11 months (82%) had breast milk in their diets. Wood was the common cooking fuel in the rural EFFECTS trial (95%), while charcoal was common in the urban DECIDE study (74%). We present results by gender for adults (DECIDE study) and by age groups for children (EFFECTS trial, when possible) because adults’ diets vary notably by gender, while child diets vary as they age in their early childhood years.

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Tables 5 and 6 summarize the most frequently consumed foods by adults and children in the DECIDE and EFFECTS studies, disaggregated by gender and age groups, respectively. The most consumed food items across both studies were stiff maize porridge, tea, rice boiled in water with oil, beans, beef relish, and green leafy relish. In the DECIDE study, the commonly consumed meat items were fish and beef relish (and beef broth for men). Ultra-processed foods such as African donuts (made of highly processed food such as flour, sugar, oil) and carbonated drinks were also frequently consumed, and these were often consumed outside the house. The most consumed foods outside of the home were carbonated sodas, chapati with oil, rice boiled in oil, tea, and fried potato chips. In the EFFECTS trial, meal consumption patterns by age group of
children revealed an interesting trend. Commonly consumed foods for children under 5 mo of age were cow milk and variations of soft porridge made of flour, maize, cassava, and finger millet porridge (watery consistency) with sugar and/or milk. Very few dietary records showed intake of legumes (in relish form), fruits (papaya and mango), and meat (fish and beef relish) among children. Among children aged 6–12 mo, diets began to include ugali (stiff porridge, has a solid consistency) and more fish either as dagaa (small, dried fish) relish or as a stew. The most consumed fruit for this age group was mango. Among children 12–18 mo of age, rice, green-leafy vegetables such as amaranth leaves relish, tea with sugar and milk, and kidney bean relish are introduced, and higher quantities of fish. By 19–24 mo of age, stiff and soft porridge, fish relish, and some additional fruits were part of the diet. There was also a more significant variety of green-leafy vegetables in the diet for older children. Median meal frequency without breastfeeding increased from 2 meals (IQR: 2, 3) for children under 6 mo of age to 5 meals (IQR: 3, 6) for children 18–25 mo of age.

Figure 3 shows histograms on the timing of meals in the DECIDE study and EFFECTS trial (non–breast-milk foods). Meals were grouped by timing—that is, 2 food items and a beverage consumed simultaneously that were accounted for as 1 meal. Urban adults typically consumed 3 meals (IQR: 3, 4) at 09:00, 13:00–14:00, and between 20:00 and 21:00. Timing of meals outside the home revealed that these comprised mostly the morning and lunch meals (Supplemental

### TABLE 2 Background characteristics of the EFFECTS trial (by age groups)

| EFFECTS trial (children) | 0–5 mo (n = 83) | 6–12 mo (n = 360) | 13–18 mo (n = 262) | 19–24 mo (n = 140) | Total (n = 845) |
|---------------------------|-----------------|-------------------|-------------------|-------------------|----------------|
| Age, y                    |                 |                   |                   |                   |                |
| 0–5 mo                    | 3.0 (3.0, 4.0)  | 9.00 (7.0, 10.0)  | 15.0 (13.0, 17.0) | 19.0 (18.0, 20.0) | 12.0 (8.0, 16.0) |
| Head of household education (%) |                 |                   |                   |                   |                |
| Up to seventh grade       | 88.6 (70)       | 87.8 (294)        | 85.0 (209)        | 88.7 (118)        | 87.1 (691)     |
| Above seventh grade       | 11.4 (9)        | 12.2 (41)         | 15.0 (37)         | 11.3 (15)         | 12.9 (102)     |
| Breastfeeding in the previous 24 h (%) |                 |                   |                   |                   |                |
| No                        | 0.0 (0)         | 2.8 (10)          | 20.1 (51)         | 59.9 (82)         | 17.1 (143)     |
| Yes                       | 100.0 (83)      | 97.2 (350)        | 79.9 (203)        | 40.1 (55)         | 82.9 (691)     |
| Common cooking fuel (%)   |                 |                   |                   |                   |                |
| Wood                      | 94.9 (75)       | 95.9 (327)        | 94.4 (235)        | 92.6 (126)        | 94.8 (763)     |
| Charcoal                  | 5.1 (4)         | 3.8 (13)          | 5.6 (14)          | 7.4 (10)          | 5.1 (41)       |
| Other                     | 0.0 (0)         | 0.3 (1)           | 0.0 (0)           | 0.0 (0)           | 0.1 (1)        |
| Grid electricity (%)      |                 |                   |                   |                   |                |
| No                        | 86.1 (68)       | 91.8 (313)        | 91.6 (228)        | 94.9 (129)        | 91.7 (738)     |
| Yes                       | 13.9 (11)       | 8.2 (28)          | 8.4 (21)          | 5.1 (7)           | 8.3 (67)       |
| Weight-for-age z-score    | −0.23 (−1.15, 0.57) | −0.47 (−1.24, 0.22) | −0.72 (−1.44, −0.09) | −0.77 (−1.65, −0.11) | −0.59 (−1.28, 0.11) |
| Household Food Insecurity Access (%) |                 |                   |                   |                   |                |
| Food secure               | 3.6 (3)         | 12.5 (45)         | 14.9 (39)         | 10.0 (14)         | 12.0 (101)     |
| Mildly food insecure      | 15.7 (13)       | 13.1 (47)         | 15.3 (40)         | 19.3 (27)         | 15.0 (127)     |
| Moderate food insecurity  | 22.9 (19)       | 26.7 (96)         | 21.4 (56)         | 18.6 (26)         | 23.3 (197)     |
| Severe food insecurity    | 57.8 (48)       | 47.8 (172)        | 48.5 (127)        | 52.1 (73)         | 49.7 (420)     |

1Values are n (%) or median (IQR). EFFECTS, Engaging Fathers for Effective Child Nutrition and Development in Tanzania.

### TABLE 3 Description of typical meals/foods consumed by participants in the DECIDE study

| DECIDE study (PLHIV adults) | Male (n = 77) | Female (n = 235) | Total (n = 312) | P |
|-----------------------------|--------------|------------------|----------------|---|
| Number of records per day   | 7 (6, 8)     | 7 (5, 8)         | 7 (5, 8)       | 0.89 |
| Meal frequency              | 3 (3, 3)     | 3 (3, 4)         | 3 (3, 4)       | 0.81 |
| What best characterizes yesterday? |             |                  |                | 0.83 |
| Typical day                 | 98.7 (75)    | 98.3 (237)       | 98.4 (312)     | 0.082 |
| Fasting day                 | 1.3 (1)      | 1.7 (4)          | 1.6 (5)        | <0.001 |
| Did you take any supplements yesterday? | Yes | 2.6 (2) | 0.4 (1) | 0.9 (3) |
| Where was this meal (food/drink) consumed? | Home | 62.9 (330) | 92.4 (1519) | 85.2 (1849) |
|                             | Work | 5.7 (30) | 2.1 (35) | 3.0 (65) |
|                             | At a friend’s house | 1.1 (6) | 0.5 (8) | 0.6 (14) |
|                             | Roadside vendor | 5.0 (26) | 1.1 (18) | 2.0 (44) |
|                             | Mamalishe (women prepared food vendors) | 10.5 (55) | 0.6 (10) | 3.0 (65) |
|                             | Restaurant | 10.9 (57) | 2.1 (34) | 4.2 (91) |
|                             | Hotel | 2.1 (11) | 0.4 (6) | 0.8 (17) |
|                             | Other | 1.9 (10) | 0.9 (14) | 1.1 (24) |

1Values are n (%) or median (IQR). DECIDE, Diet, Environment, and Choices of positive living; PLHIV, persons living with HIV.
### TABLE 4  Description of typical meals/foods consumed by participants in the EFFECTS trial

| EFFECTS trial (children) | 0–5 mo (n = 83) | 6–12 mo (n = 360) | 13–18 mo (n = 262) | 19–24 mo (n = 140) | Total (n = 845) | P (adjusted for village clustering) |
|--------------------------|-----------------|------------------|--------------------|--------------------|-----------------|-----------------------------------|
| % Children breastfed yesterday | 100.0 (83) | 97.5 (351) | 77.9 (204) | 38.6 (54) | 81.9 (692) | <0.001 |
| Breastfeeding frequency | 7 (5, 8) | 5 (4, 7) | 4 (2, 5) | 0 (0, 3) | 5 (3, 6) | <0.001 |
| Meal frequency (including breastfeeding) | 9 (7, 11) | 9 (7, 11) | 8 (6, 10) | 6 (4, 8) | 8 (6, 10) | <0.001 |
| What best characterizes yesterday? | Typical day | 96.4 (80) | 96.7 (348) | 97.3 (255) | 97.1 (136) | 96.9 (819) | 0.764 |
| Holiday/special day/Other | 3.6 (3) | 3.3 (12) | 2.7 (7) | 2.9 (4) | 3.1 (26) | |

1Values are n (%) or median (IQR). EFFECTS, Engaging Fathers for Effective Child Nutrition and Development in Tanzania.

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Figure 2, which are consumed outside the home compared to evening meals. Among those who reported eating food away from home, men had a more significant share of the total energy intake (median: 54%) than women (median: 39%). Distribution of meal timings for children (EFFECTS trial) revealed that morning meals and evening meals were highly structured in a smaller time window compared with midday meals (i.e., less variability in the distribution of the timing among all children).

Table 7 shows the summary of nutrient intakes by gender in the DECIDE study. Urban men consumed a median intake of 3040 kcal, while women consumed 2468 kcal. Timing of energy intake across meals and over weekdays, as shown in Figure 4, illustrates the differences by gender. For men, the first 2 meals typically had a higher proportion of daily energy consumption, compared with evening or late-night meals, except most notably on Fridays (which are considered a holiday for Muslims). The opposite trend was observed for women, whose first meal typically provided <400 kcal, while a higher share of daily energy was consumed later in the day. More women reported consuming the fourth meal (n = 143) compared with men (n = 43). Gender differences in protein intake (especially from animal-source food), overall fat intake, and zinc were also observed. There were no differences observed in carbohydrates, fiber, calcium, iron, vitamin A, or folate intake. Median micronutrient intakes for iron (10% bioavailability) and zinc (moderate availability) met the UN Recommended Nutrient Intakes (RNI) for respective age and sex groups (24). However, median calcium, vitamin A, and folate intakes remained below the UN RNI (24).

Table 8 shows the summary of nutrient intakes in the EFFECTS trial. Children’s intake of all nutrients increased with age, where median energy intake ranged from 170 to 600 kcal/d among children 0–24 mo of age. Median micronutrient intakes for calcium, iron, zinc, and vitamin A were below the UN RNI for children 9–24 mo of age (24). However, median intakes for folate exceeded the UN RNI with 35.6 μg/d compared with the breast-milk–adjusted UN RNI of 27.6 μg/d for children aged 9–11 mo (24).

### TABLE 5  Most frequently consumed food by adults and children in DECIDE and EFFECTS studies

| DECIDE female PLHIV | Frequency (n = 1614) | DECIDE male PLHIV | Frequency (n = 544) |
|---------------------|----------------------|-------------------|---------------------|
| 1. Maize ugali (stiff porridge) | 230 | 1. Maize ugali (stiff porridge) | 66 |
| 2. Tea without milk, with sugar | 181 | 2. Tea without milk, with sugar | 47 |
| 3. Rice boiled with oil | 123 | 3. Rice boiled with oil | 39 |
| 4. Beans, kidney, mature, boiled without salt | 59 | 4. Chapati with oil | 26 |
| 5. Green leaf, medium, relish without oil | 51 | 5. Beef relish with oil | 25 |
| 6. Donut-African | 45 | 6. Beans, kidney, mature, boiled without salt | 23 |
| 7. Chapati with oil | 41 | 7. Carbonated, beverage, Coca-Cola | 21 |
| 8. Fish relish with oil | 39 | 8. Donut-African | 16 |
| 9. Cassava, fried | 34 | 9. Green leaf, medium, relish without oil | 12 |
| 10. Carbonated, beverage, Coca-Cola | 33 | 10. Tea with milk and sugar | 11 |
| 11. Beef relish with oil | 32 | 11. Banana, ripe | 9 |
| 12. Sweet potato leaf | 32 | 12. Beef broth with oil | 9 |
| 13. Fish, fried | 27 | 13. Bread, white | 9 |
| 14. Banana, ripe | 25 | 14. Sweet potato leaf | 9 |
| 15. Fish relish with coconut milk | 23 | 15. Fish relish with oil | 8 |
| 16. Small dried fish, fried | 23 | 16. Kidney bean relish with oil | 8 |
| 17. Potato chips, fried | 19 | 17. Potato leaf relish with oil | 8 |
| 18. Rice with coconut milk | 19 | 18. Fish, fried | 7 |
| 19. Small dried fish with tomatoes and oil | 19 | 19. Potato chips, fried | 7 |
| 20. Bread, white | 18 | 20. Cabbage, onion salad | 6 |

1Numbers represent frequency out of total meals across all dietary recalls. DECIDE, Diet, Environment, and Choices of positive living; EFFECTS, Engaging Fathers for Effective Child Nutrition and Development in Tanzania; PLHIV, persons living with HIV.
| Most frequently consumed food | Frequency | Most frequently consumed food | Frequency | Most frequently consumed food | Frequency | Most frequently consumed food | Frequency |
|-------------------------------|-----------|-------------------------------|-----------|-------------------------------|-----------|-------------------------------|-----------|
| Milk whole, 3.25% milk fat    | 81        | Maize ugali (stiff porridge)  | 162       | Maize ugali (stiff porridge)  | 162       | Maize ugali (stiff porridge)  | 102       |
| Mix flour porridge with sugar | 41        | Mix flour porridge with sugar | 120       | Mix flour porridge with sugar | 120       | Maize porridge without sugar and milk | 84       |
| Maize porridge with sugar     | 14        | Maize porridge with sugar     | 108       | Maize porridge with sugar     | 108       | Maize porridge with sugar     | 56        |
| Cassava porridge with sugar   | 10        | Maize porridge without sugar and milk | 94   | Maize porridge without sugar and milk | 94 | Maize porridge with sugar | 55 |
| Maize porridge without sugar and milk | 9   | Fish relish without oil | 68 | Fish relish without oil | 68 | Fish relish without oil | 36 |
| Cassava porridge (Uji wa Muhogo) | 8 | Mango, ripe, fresh—EP | 60 | Mango, ripe, fresh—EP | 60 | Fish relish with oil | 36 |
| Sorghum porridge with sugar   | 6        | Cassava stiff porridge       | 55        | Cassava stiff porridge       | 55        | Cassava and red sorghum ugali | 31 |
| Sorghum porridge without sugar or milk | 6 | Maize sorghum ugali (stiff porridge) | 54 | Maize sorghum ugali (stiff porridge) | 54 | Mango, ripe, fresh—EP | 28 |
| Mango, ripe, fresh—EP         | 4        | Fish relish with oil          | 54        | Fish relish with oil          | 54        | Maize sorghum ugali (stiff porridge) | 25 |
| Finger millet and sorghum porridge | 4 | Rice boiled with oil | 43 | Rice boiled with oil | 43 | Small dried fish with tomatoes and oil | 25 |
| Cassava porridge with milk and sugar | 4 | Small dried fish with tomatoes and oil | 43 | Small dried fish with tomatoes and oil | 43 | Cassava stiff porridge | 24 |
| Maize porridge with sugar and milk | 3 | Milk whole, 3.25% milk fat | 40 | Milk whole, 3.25% milk fat | 40 | Sweet potato, boiled | 20 |
| Fish relish without oil       | 3        | Maize porridge with sugar and milk | 40 | Maize porridge with sugar and milk | 40 | Kidney bean relish with oil | 19 |
| Cassava flour, ugali          | 3        | Cassava and sorghum porridge without sugar or milk | 30 | Cassava and sorghum porridge without sugar or milk | 30 | Tea without milk, with sugar | 19 |
| Mango juice                   | 2        | Kidney bean relish with oil   | 28        | Kidney bean relish with oil   | 28        | Maize porridge with sugar and milk | 18 |
| Millet porridge with sugar    | 2        | Cassava and red sorghum ugali | 27 | Cassava and red sorghum ugali | 27 | Milk whole, 3.25% milk fat | 17 |
| Cassava stiff porridge        | 2        | Tea without milk, with sugar  | 25        | Tea without milk, with sugar  | 25        | Cassava and maize ugali | 17 |
| Papaya, ripe                  | 1        | Fish, fresh, stew             | 24        | Fish, fresh, stew             | 24        | Cassava and sorghum porridge without sugar or milk | 17 |
| Maize ugali (stiff porridge)  | 1        | Sweet potato, boiled          | 24        | Sweet potato, boiled          | 24        | Small dried fish with tomatoes and oil | 15 |
| Maize and sorghum ugali (stiff porridge) | 1 | Papaya, ripe | 23 | Papaya, ripe | 23 | Fish, fresh, stew | 14 |
| Beef relish with oil          | 1        | Amaranth, leaves, picked, boiled, drained (without salt) | 23 | Amaranth, leaves, picked, boiled, drained (without salt) | 23 | Cassava, millet and sorghum porridge | 14 |
| Kidney bean relish with oil   | 1        | Maize, porridge, milk         | 23        | Maize, porridge, milk         | 23        | Amaranth, leaves, picked, boiled, drained (without salt) | 11 |
| Kidney bean relish without oil| 1        | Cassava flour ugali           | 19        | Cassava flour ugali           | 19        | Yogurt, plain, whole milk | 9 |
| Cassava and red sorghum ugali | 1        | Cassava, millet and sorghum porridge | 18 | Cassava, millet and sorghum porridge | 18 | Green leaf, medium, relish with oil | 9 |
| Maize porridge milk           | 1        | —                              | —         | —                              | —         | —                              | —         |
| **TABLE 6** Most frequently consumed food by children in EFFECTS trial

| 0–5 mo (n = 210) | 6–12 mo (n = 1634) | 13–18 mo (n = 1576) | 19–24 mo (n = 911) |
|------------------|-------------------|---------------------|-------------------|
| Total            |                   |                     |                   |
| Calories         |                   |                     |                   |
| Fat              |                   |                     |                   |
| Carbohydrate     |                   |                     |                   |
| Protein          |                   |                     |                   |

1 Numbers represent frequency out of total meals across all dietary recalls. EFFECTS, Engaging Fathers for Effective Child Nutrition and Development in Tanzania; EP, edible parts.
Discussion

Here we have developed and describe a tablet-based dietary intake tool (TZ-24hr-DR) that is easy to administer in Tanzania to collect dietary information from adults and children in an urban and a rural setting. We streamlined the transformation of raw data into food groups, meal timings, macronutrients, and micronutrients by embedding the same meal codes as the FCTs. Use of the multiple-pass method and a summary review feature at the end of 24-h recall aided in collecting accurate data. We were able to run real-time analysis of dietary data because the data were sent to the server within hours of data collection. Real-time analyses enabled us to identify issues such as extreme amounts or when “two mornings of dietary data” were collected (technically within 24 h, e.g., 08:00 yesterday to 08:00 today), and nonplausible or unknown ingredients, where immediate feedback was sent to the field with automated reports to remedy those errors. We found gender differences among adult PLHIV regarding location of food consumption, share of energy intakes within a day, and in nutrients.

We describe the timing and the location of meals and energy intake (among adults) and characterized the meal structures among an urban population in Tanzania. There is virtually no post-processing involved to examine the timing and location of meal consumption patterns. Greater consumption of food outside the home was reported by men (37%) than women (7%), and most of these occasions occurred in the morning and afternoon meals (Supplemental Figure 2). Overall, food consumption outside the home among DECIDE participants (15% in adults) was lower compared with urban studies done in Kenya and Ghana, where 77–81% reported eating out (26). These differences could be due to the sample and location (DECIDE is peri-urban compared with these studies that were in urban settings). Generally, there appeared to be a trend where men were eating out for 2 out of 3 meals (breakfast and lunch outside the home), and men also reported a more significant share of total daily expenditure of food consumed outside the home compared with women, which is comparable to another study conducted in Tanzania (27). Taken together, this adds to the larger trend observed in urban African cities, where an estimated one-quarter of the urban population eat daily meals outside the home, and many of these include consumption of “ultra-processed prepared” foods, such as rice with sauce and potato fries, away from home along with the consumption of other ultra-processed foods such as sodas and African donuts (3). We also see these trends translate into the timing of energy intakes where men show greater energy intakes in the first 2 meals (480–510 kcal) compared with their later meals (315–450 kcal) (Figure 4).

Nutrient estimates for the adult intakes from the TZ-24hr-DR were similar to a dietary validity study conducted in the same community (28). This study validated a food-frequency questionnaire (FFQ) with 2 paper-based 24-h recalls conducted in the same study setting among adults (28). The energy estimates from TZ-24hr-DR were closer to the FFQ estimates (mean of 2599 kcal), while estimates on macronutrient intake were between the FFQ and paper-based 24-h recall, especially protein intakes (28). Women's energy estimates from the TZ-24hr-DR (median: 2469 kcal) were also aligned with another FFQ study conducted among PLHIV pregnant women in peri-urban Dar es Salaam, Tanzania (median: 2532 kcal) (29). Mean folate, vitamin A, and iron ranges from the TZ-24hr-DR align more closely with the estimates from the paper-based 24-h recall (28). Zack and colleagues (28) concluded that the FFQ was able to yield good estimates of macronutrients and minerals but not vitamins. It appears that the TZ-24hr-DR tool is a good measure of macro- and micronutrients for adults, given that all the micronutrients estimated from the tablet-based recall range were closer to the paper-based methods from Zack et al. conducted among adults from the same study setting. However, additional validation studies are needed to affirm these findings, especially for calcium intakes (28).

Rural children in the Mara region were introduced to semi-solid foods before 6 mo of age, which consisted of different mixed-grain and staple porridges such as sorghum, cassava, millets, and maize. The variety of green-leafy vegetables in children’s diets generally increased with age. Only morning and evening meals appeared to be more structured (in terms of timing), perhaps reflecting the time use of caregivers and

**FIGURE 3** Timing of meals in DECIDE study (PLHIV adults; top panel) and EFFECTS trial (children <2 y of age, non-breast-milk foods; bottom panel). DECIDE, Diet, Environment, and Choices of positive living; EFFECTS, Engaging Fathers for Effective Child Nutrition and Development in Tanzania; PLHIV, persons living with HIV.
Table 7: Median nutrient intakes from the DECIDE study by gender (PLHIV adults)\(^1\)

|                      | Tablet-based estimates                      | Total (n = 312)                      |
|----------------------|--------------------------------------------|-------------------------------------|
| **Male (n = 77)**    |                                            |                                     |
| Energy, kcal         | 3040.7 (2099.9, 4351.5)                    | 2607.0 (1775.6, 3632.8)             |
| Protein, g           | 89.6 (44.7, 151.7)                         | 66.9 (42.2, 114.2)                 |
| Animal-source protein, g | 35.3 (4.4, 95.9)                  | 26.7 (0.0, 65.5)                   |
| Fat, g               | 112.2 (50.1, 180.7)                        | 79.7 (43.9, 144.7)                 |
| Carbohydrates, g     | 407.3 (240.3, 484.9)                       | 377.8 (240.3, 488.8)               |
| Fiber, mg            | 24.4 (19.1, 33.9)                          | 24.7 (16.9, 34.6)                  |
| Calcium, mg          | 311.0 (119.2, 960.4)                       | 350.9 (156.6, 1201.7)              |
| Iron, mg             | 13.3 (8.0, 18.6)                           | 11.4 (7.9, 17.8)                   |
| Zinc, mg             | 11.2 (6.3, 16.6)                           | 8.9 (5.9, 14.1)                    |
| Vitamin A, μg RE     | 259.1 (97.0, 909.0)                        | 260.8 (76.5, 811.2)                |
| Folate, μg           | 298.4 (173.0, 455.9)                       | 281.1 (163.8, 440.4)               |
|                      |                                            |                                     |
| **Female (n = 235)** |                                            |                                     |
| Energy, kcal         | 2468.7 (1732.6, 3445.3)                    | 2675.0 (1775.6, 3632.8)            |
| Protein, g           | 63.5 (41.3, 106.5)                         | 66.9 (42.2, 114.2)                 |
| Animal-source protein, g | 20.2 (0.0, 60.2)                  | 26.7 (0.0, 65.5)                   |
| Fat, g               | 73.9 (42.5, 131.6)                         | 79.7 (43.9, 144.7)                 |
| Carbohydrates, g     | 363.2 (239.7, 501.3)                       | 377.8 (240.3, 488.8)               |
| Fiber, mg            | 24.8 (16.4, 34.9)                          | 24.7 (16.9, 34.6)                  |
| Calcium, mg          | 362.7 (167.6, 1342.2)                      | 350.9 (156.6, 1201.7)              |
| Iron, mg             | 11.3 (7.7, 17.2)                           | 11.4 (7.9, 17.8)                   |
| Zinc, mg             | 8.7 (5.6, 13.0)                            | 8.9 (5.9, 14.1)                    |
| Vitamin A, μg RE     | 276.1 (72.6, 771.1)                        | 260.8 (76.5, 811.2)                |
| Folate, μg           | 268.4 (159.5, 433.6)                       | 281.1 (163.8, 440.4)               |

\(^1\)Values are medians (IQR) from tablet-based recall. DECIDE, Diet, Environment, and Choices of positive living; PLHIV, persons living with HIV; RE, retinol equivalents.

Livelihoods. Children’s micronutrient estimates were also comparable to another study conducted in rural Manyara, Tanzania, where paper-based 24-h recalls were collected from children 9–24 mo of age (30). In our study, we found very low intakes of vitamin A, calcium, and folate (especially among the younger age groups), and medium intakes of zinc and iron.

We compared children’s energy intake with acceptable energy ranges identified by Htet et al. (13) and based on Dewey and Brown’s (31) recommendations. The acceptable energy intake range for breastfed children is 100–600 kcal for 6–8-mo-old children, 200–750 kcal for 9–11-mo-old children, and 500–1100 kcal for 12–23-mo-old children (13, 31). Based on these ranges, 60.8% of the breastfed children (n = 682) and non-breastfed children (n = 153) met the acceptable energy intakes. These estimates were also on par with other tablet-based methods, which appear to have lower misreporting rates on energy intakes than paper-based recalls (13, 32). Closer examination of the children outside the acceptable energy intake reveals that an additional 20% of breastfed children and 30% of non-breastfed children fall within 200 kcal of acceptable energy ranges. Further examination of sources of foods, market availability, feeding practices, and overall bioavailability of these micronutrients will be conducted in planned analyses to give a contextual detail on the local availability of micronutrient-rich foods.

This study adds a new tool (available in Harvard dataverse https://doi.org/10.7910/DVN/NEMC70), database of new recipes (n = 28, see Supplemental Table 1), and new portion-size estimates (n = 88) to estimate dietary intake rapidly. This tool is useful for...
estimating both macro- and micronutrients in Tanzania, is a flexible platform to collect dietary data for children and adults, and is a practical tool to conduct dietary recalls among multiple members of the household. Using the recipe feature, we collected 825 recipes (data not shown) from respondents that could be further analyzed to examine variations from the Tanzanian FCT. Although direct validation was not conducted, the estimates appear to be comparable to recent studies conducted in Tanzania.

Existing FCTs within the country were instrumental in developing this tool, linking datasets with real-time analysis. Out of 54 countries in Africa, there are only 21 with a food-composition database, of which 8 were recently updated in the last decade. Given the availability and use of the Kenyan FCT (2018) in this analysis, and more recently, the availability of the Malawi FCT (2019) (33), the tool could be expanded for use in East Africa. This adds to the growing number of electronic 24-h data-collection tools available in LMIC contexts (9) that could be tremendously useful in a variety of contexts. For example, this tool could be used to examine transition in food systems, availability of food, or timing and location of meals to understand meals consumed outside the home and other dietary risk factors, dietary surveillance, or more importantly, in the context of interventions, such as food-fortification programs.

**Acknowledgments**

We acknowledge and are grateful for the collaboration and support of the families of the DECIDE study and EFFECTS trial and the dedication of the regional and field staff. We thank Dr. Gwenyth Lee for providing insightful feedback on the manuscript. The authors’ responsibilities were as follows—RA: designed the tools with assistance from BC, led the analysis, and wrote the manuscript with input from all co-authors; II: programmed the tool with supervision from IL; RA, NG, MM-S, JK, GL, and LG: led the implementation of the study that provided data for these analyses; DM, AM, and SN: led the fieldwork and data collection; DM, SN, and CP: conducted the training; SN, SLE, MB, and CKV: aided in new portion-size and recipe development; RA and NG: have the primary responsibility for the final content; and all authors: read and approved the final manuscript.

**Data Availability**

Data described in the manuscript and code will be made available upon request pending ethical and study team approvals. Tanzanian dietary tablet collection tool is available on Harvard dataverse for research purposes (https://doi.org/10.7910/DVN/NEMC70). For further information, please contact rambikap@purdue.edu.

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**TABLE 8 Median Nutrient intakes among children 0–25 mo of age from the EFFECTS trial1**

|                        | EFFECTS (children) |
|------------------------|--------------------|
|                        | 0–5 mo (n = 83)    | 6–12 mo (n = 360) | 13–18 mo (n = 262) | 19–25 mo (n = 140) |
| Energy, kcal           | 169.2 (84.6, 292.3)| 500.4 (312.7, 732.5)| 770.8 (554.0, 1137.2)| 932.5 (591.5, 1262.2)|
| Protein, g             | 4.5 (2.3, 8.7)     | 11.4 (5.8, 20.3)  | 21.0 (14.1, 30.6)  | 23.8 (16.1, 32.7)  |
| Animal-source protein, g| 2.3 (0.0, 6.8)     | 4.3 (0.0, 11.0)   | 8.6 (2.6, 17.2)    | 9.2 (2.8, 17.7)    |
| Fat, g                 | 6.4 (1.8, 11.3)    | 12.9 (5.9, 22.7)  | 17.3 (9.8, 28.6)   | 19.8 (11.5, 31.5)  |
| Carbohydrates, g       | 23.6 (9.5, 38.6)   | 78.3 (46.9, 116.4)| 124.1 (78.9, 204.4)| 158.4 (98.0, 220.3)|
| Fiber, mg              | 0.9 (0.0, 3.6)     | 6.5 (3.4, 10.0)   | 10.4 (6.1, 15.3)   | 11.4 (8.2, 17.3)   |
| Calcium, mg            | 93.6 (46.8, 243.2) | 148.4 (59.6, 472.3)| 348.4 (98.2, 788.2)| 404.6 (107.7, 889.9)|
| Iron, mg               | 0.5 (0.2, 1.0)     | 2.8 (1.4, 4.6)    | 5.2 (3.3, 7.2)     | 6.5 (4.3, 8.8)     |
| Zinc, mg               | 0.6 (0.4, 1.1)     | 1.7 (0.9, 3.4)    | 3.5 (2.3, 5.0)     | 3.9 (2.4, 6.0)     |
| Vitamin A, μg RE       | 39.5 (1.0, 59.2)   | 36.8 (2.9, 97.9)  | 91.0 (25.8, 257.6) | 99.5 (38.7, 222.9) |
| Folate, μg             | 10.9 (7.0, 21.4)   | 35.6 (16.3, 64.6) | 66.5 (40.4, 100.7) | 78.5 (54.1, 118.9) |

1Values are medians (IQR). EFFECTS, Engaging Fathers for Effective Child Nutrition and Development in Tanzania; RE, retinol equivalents.
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