Development and Validation of a Data-Based Food Frequency Questionnaire for Adults in Eastern Rural Area of Rwanda

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ABSTRACT: This study aimed to develop and evaluate the validity of a food frequency questionnaire (FFQ) for rural Rwandans. Since our FFQ was developed to assess malnutrition, it measured energy, protein, vitamin A, and iron intakes only. We collected 260 weighed food records (WFRs) from a total of 162 Rwandans. Based on the WFR data, we developed a tentative FFQ and examined the food list by percent contribution to energy and nutrient intakes. To assess the validity, nutrient intakes estimated from the FFQ were compared with those calculated from three-day WFRs by correlation coefficient and cross-classification for 17 adults. Cumulative contributions of the 18-item FFQ to the total intakes of energy and nutrients reached nearly 100%. Crude and energy-adjusted correlation coefficients ranged from −0.09 (vitamin A) to 0.58 (protein) and from −0.19 (vitamin A) to 0.68 (iron), respectively. About 50%–60% of the participants were classified into the same tertile. Our FFQ provided acceptable validity for energy and iron intakes and could rank Rwandan adults in eastern rural area correctly according to their energy and iron intakes.

KEYWORDS: dietary assessment, weighed food record, food frequency questionnaire, relative validity, Rwanda

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Introduction

Rwanda has made impressive progress in economic and social development since the 1994 genocide.[1] However, 16.3% of Rwandans, mostly villagers, live in extreme poverty and are unable to afford basic food, and 39.1% of them live on less than the national poverty line.[2] Elucidating the nutritional status of the population is significant because it is the outcome of a wide range of social and economic conditions and is a sensitive indicator of the overall level of development.[3] Information of dietary intake is needed for various purposes and essential for monitoring general trends in the nutritional condition, selecting and implementing effective policies, and evaluating the program impact.[3] In developing countries such as Rwanda, however, dietary assessments have seldom been carried out. Measurement of food and nutrient intakes is challenging due to lack of budget, equipment, skilled personnel, participants' motivation, and literacy.[4] Simple and inexpensive methods can be employed. Among various dietary assessment methods, food frequency questionnaire (FFQ) has been considered the most appropriate method in large-scale epidemiological studies. This is because it is easy and quick to administer and the cost is relatively low.[5,6] It can measure long-term habitual dietary intake and data from an FFQ can be used to elucidate diet–disease relations through ranking participants based on their usual dietary intakes.[7,8] FFQs need to be developed specifically for each population to produce valid and reliable dietary data.[9] In addition, validation studies should be performed to examine the degree that an FFQ coincides with the participants' true intake because energy and nutrient intakes estimated from it are subject to substantial errors, both systematic and random.[10,11]

Since there is no FFQ available for rural Rwanda where equipment and skilled personnel for dietary assessment are scarce, this study aimed to develop a data-based FFQ for children and adults in rural Rwanda to evaluate a nutrition project and assess validity of the FFQ by using weighed food records (WFRs) as a reference.

Methods

Study sites. The Republic of Rwanda is located in Central and East Africa. The field surveys were conducted in two areas in Rwanda, namely, Rukara sector and Mwiri sector, in Kayonza district, Eastern Province (Fig. 1). These sectors are characterized by hot and humid climate with average temperatures between 18°C and 26°C. A long rainy season lasts from mid-February to mid-May and a short one from mid-September through early December.

According to a census in 2008, 31,283 people live on an area of 64 km^2 in Rukara sector and 23,239 people live on an area of 540 km^2 in Mwiri sector.[12] Most of the people in these areas engage in agriculture and depend on subsistence agriculture for food. Since malnutrition and poverty rates of Rukara sector have been high, World Vision Rwanda (WVR), in collaboration with World Vision Japan (WVJ), a Christian development, advocacy, and relief organization, has conducted a nutrition project, which is called Gwiza Area Development Program (Gwiza ADP) in this sector. There has been no intervention by WVR in the Mwiri sector. In this article, results of a validation study using the whole sample are shown because we confirmed that similar results were obtained when we separately analyzed each sector.

Sampling. Japanese researchers and the staff of World Vision's Gwiza ADP selected 20 households in Rukara sector and 12 households in Mwiri sector (a total of 32 households). We selected households with at least two adult members (aged 18 years or older). There were several households that fulfilled the criterion, and therefore we used convenience sampling. Since the researchers had to visit at least two households (at the most, around 10 households) to obtain a consent form while conducting the dietary survey (WFRs and FFQ) at another household in a day, it was necessary to select households within a close distance.

Study design and participants. From the 32 households, a total of 162 participants (70 males and 92 females) aged 1–69 years were recruited (Fig. 2). In order to develop a food list and estimate individual's usual portion size of each food for children and adults, the WFRs were conducted among the 162 participants.

As shown in Figure 3, the WFRs were conducted in March 2013, August 2013, and March 2014 in Rukara sector. In Mwiri sector, they were conducted in August 2013, March 2014, and August 2014. In these areas, people depend on local food production because infrastructure for preservation and transportation is lacking. Therefore, seasonal variations of food availability, both in terms of quantity and quality, are large. In order to observe seasonal variations in food intake, we conducted the WFRs twice a year, in March and August, that is, in rainy season and dry season.

In order to assess intraindividual differences, we tried to visit the same households three times. After completing the WFRs, the FFQ was conducted in August 2014 in both sectors. We administered it to the 162 participants from whom the WFRs were collected (Fig. 2).

Validation study of the FFQ was carried out only for adults aged 18–69 years. In the Dietary Reference Intakes for Japanese 2015, people aged 18–69 years are categorized as adults and those older than 69 years are classified as elderly.[13] The Nutrition Information Centre of the University of Stellenbosch (NICUS) in South Africa also applies a similar classification where people aged 71 years and older are regarded as elderly.[14] We followed these references and the cutoff point for adults is set at 69 years.

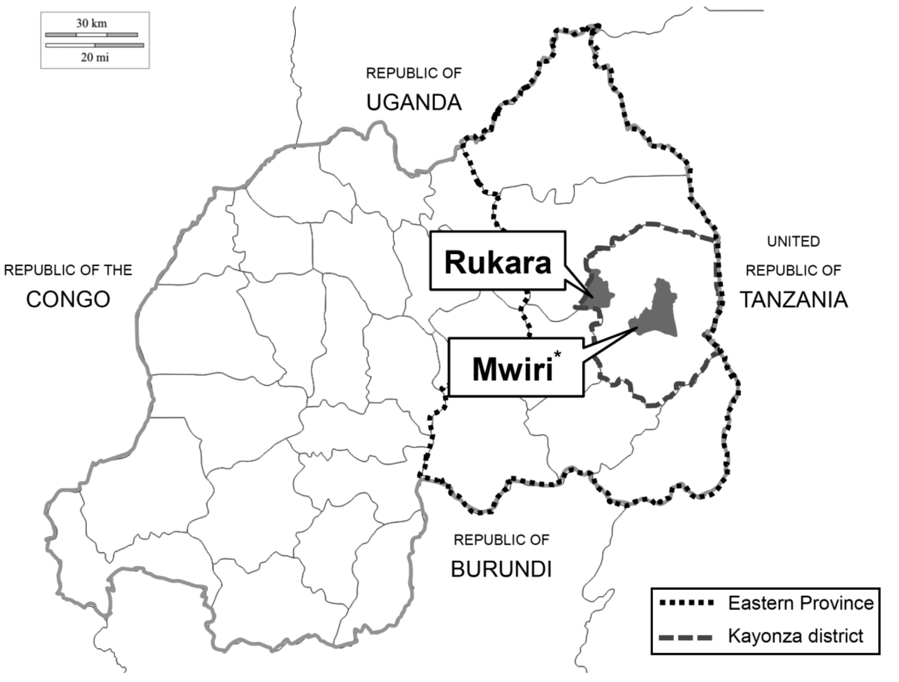

Figure 1. Location of Rukara and Mwiri sectors in Kayonza district, Eastern Province, Rwanda.
Notes: *Area of Mwiri sector is not containing Akagera National Park. Modified from http://d-maps.com/carte.php?num_car=4895&lang=en.

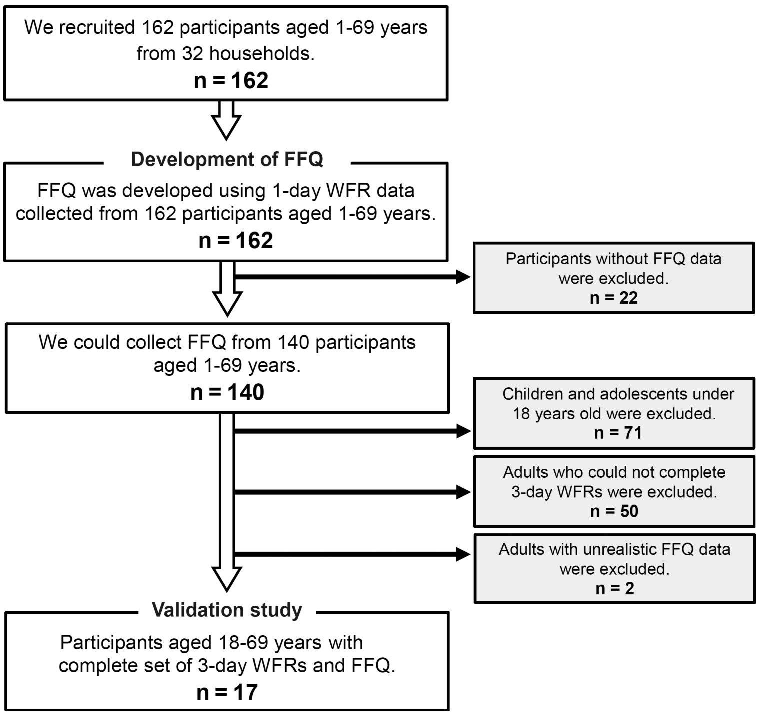

Figure 2. The number of participants by analyses.
Abbreviations: WFR, weighed food record; FFQ, food frequency questionnaire.

Validity of the FFQ was assessed by comparing energy and nutrient intakes estimated from the FFQ and the average of the three-day WFRs. For the development of food list in the FFQ, we used WFR data from the 162 participants of varying ages in order to cover between-person variation in food choice by age. For the validation study of the FFQ, we used data from 17 adults aged 18–69 years only because portion size data collected from the limited number of children and adolescent were insufficient to provide median portion size by sex and age groups.

As shown in Figure 2, only adult participants who have a complete set of three-day WFRs and single FFQ were included in the validation study. One adult was excluded since her total energy intake estimated from the FFQ was greater than 3,500 kcal, being considered unrealistically high in the study area. Another adult was excluded since her total energy intake estimated from the FFQ largely differed from daily energy requirement.[15]

Development of FFQ.

WFRs. Since we directly weighed and recorded the amount of intake (ie, direct-observed WFR), no participants had to self-report their intake. We also did not have adults or other family members discuss or report their children's intake.

This method was designed by one of the authors, NS, and has been applied in another developing country.[16,17] In this study, three Japanese master students who majored in

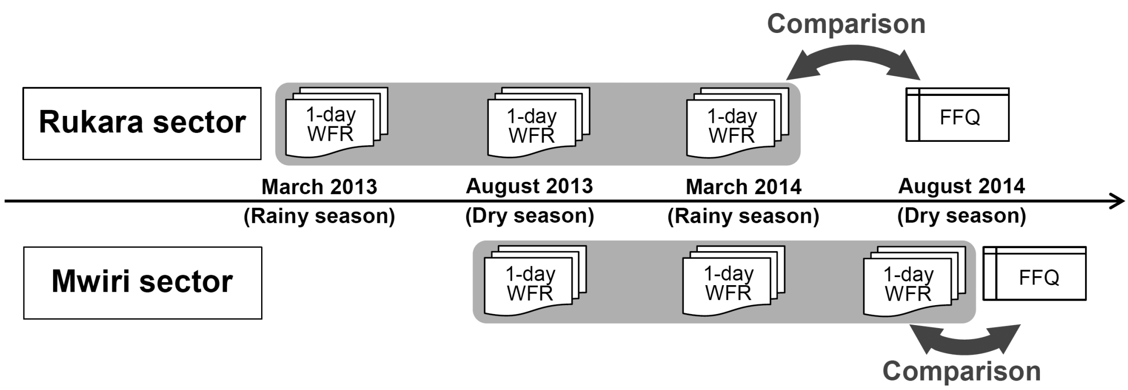

Figure 3. Design for validation study.
Abbreviations: WFR, weighed food record; FFQ, food frequency questionnaire.

food science and nutrition were trained on the first day of the field survey. NS and two master students were qualified registered dietitians. Since all weighing and recording were conducted by these four researchers, it was not necessary to train the participants.

The WFRs were conducted on weekdays since local staffs were not permitted to work on weekends for religious reasons. One research team consisting of one Japanese researcher and a staff of WVR stayed in one house from early morning to evening in order to observe and record the quantity of ingredients, portion amounts, and, if any, leftovers of the dish for the three main meals (breakfast, lunch, and dinner) and snacks.

The detailed procedure of the WFR that measured individual intake was as follows: first, we weighed all raw ingredients and seasonings that were going to be used for cooking. After cooking, we weighed the whole cooked food and calculated the percentages of each raw ingredient included in it (proportion coefficient). Second, to determine the individual's portion size (consumption amount per meal), we weighed not only the served food but also, if any, the amount of leftover and additionally served food. Then, we calculated the participant's intake of each raw ingredient by multiplying the portion size of the dish (in grams) by each ingredient's proportion coefficient. If a family member was absent, we asked if he/she had consumed anything away from home when he/she came back. We then calculated the nutrient intake for each participant using the food composition tables of Uganda,[18] a neighboring country of Rwanda because we could not find it for Rwandans.

During the survey, some men drunk sorghum alcohol, but it is not listed in the tables. Therefore, we bought a bottle of sorghum alcohol at a store in Rukara sector and sent it to SUNATEC, a Japanese Food Analysis Technology Center, for chemical analysis of energy, macronutrients (protein, lipid, and carbohydrate), and iron. In this survey, we were interested in the analysis of energy and three nutrients, namely, protein, iron, and vitamin A, since protein energy malnutrition and these two micronutrient deficiencies are major dietary problems in Rwanda.[19] According to food composition tables, however, no alcohol beverage contain vitamin A. Therefore, the chemical analysis was not performed for vitamin A.

Selection of food items listed in FFQ. Any food items consumed by more than two participants were included in the FFQ, but we excluded the items whose median portion size contained a small amount of energy. Some food items that were not observed in the WFRs but commonly sold at stores in the study areas and significantly contribute to energy and nutrient intakes and differentiation of individuals were added in the food list. We examined the food list by percent contribution to energy and nutrient intakes.[20,21]

Determination of portion sizes of food items. Data-based FFQ asks consumption frequency only. The same median portion size calculated from the WFRs was adopted for the people in the same age and sex group. Due to the limited number of participants, we classified them widely into three age groups (1–4 years, 5–17 years, and 18 years and older). If there were no data on portion size of a certain food item for a certain group, we applied the median portion size of all participants. We got no information about the portion sizes of egg and commercial beverages since they were not observed in the WFRs. We applied the following portion sizes: portion size of egg is 50 g, the average egg weight. The portion size of commercial beverages is 200 g because soda and cola were sold in 200 mL bottles in the survey area.

Validation of FFQ.

Administration of FFQ. The FFQs were collected from the same participants from whom the WFRs were collected (Fig. 2). The English written FFQ was administered by a staff of WVR who read English and spoke Kinyarwanda. For small children who could not answer the questions, their adult family members answered. The mother judged if her child could answer the FFQ.

Our FFQ did not specify the recall time frame and asked the participants' usual intake like other FFQs.[22–25] We considered that the mean intake calculated from the three-day WFRs scattered over two years could also represent their usual intake. That is, both the FFQ and the WFRs assessed the participants' usual intake.

Our FFQ asked consumption frequency by nine categories: (1) never, (2) once per month or less, (3) two to three times per month, (4) once per week, (5) two to four times per week, (6) five to six times per week, (7) once per day, (8) twice per day, and (9) more than three times per day.

Calculation of energy and nutrient intakes from FFQ. Energy and nutrient intakes from a food item was calculated as follows: consumption frequency adjusted per day was multiplied by energy and nutrient contents in median portion size for the age and sex group.

For example, for computation of energy and nutrient intakes from "milk/tea with milk and sugar", we used energy and nutrient contents in median portion size of this item. The WFRs provided six recipe data of "milk/tea with milk and sugar". We averaged the grams of milk and sugar used in the six recipes and calculated the energy and nutrient contents per 100 g of "milk/tea with milk and sugar" made with the average recipe. Energy and nutrient contents in median portion size can be calculated by multiplying them by the median portion size (g)/100.

Total energy and nutrient intakes per day were calculated by summing up of all the 18 items as described above.

Statistical analyses. Kruskal–Wallis test was used to determine whether the median portion size was different among the three adult age groups (18–29, 30–49, and 50–69 years). Mann–Whitney's *U* test was used when portion size data were available only for the two age groups.

To examine the food list, we used percent contribution to energy and nutrient intakes.

For the validation study, energy and nutrient intakes were log-transformed (log10) to reduce skewness and approximate to the normal distribution. Pearson's correlation coefficient for energy and nutrient intakes was calculated between the FFQ and three-day WFRs before and after adjustment for total energy intake. Energy adjustment was executed using regression models with energy intake as an independent variable and nutrient intake as a dependent variable to minimize the variation of nutrient intake caused by differences in energy intake.[8,26] Cross-classification analysis was conducted to examine the ability of the FFQ to classify individuals exactly into the same category as by the three-day WFRs. Participants were classified into tertiles based on energy and nutrient intakes estimated by the two methods, and their percentages classified into the same, adjacent, and opposite tertiles were computed.

Statistical Package for Social Sciences for Windows version 21.0 (IBM SPSS Inc.) was used for all statistical analyses. Statistical significance was set at $P < 0.05$.

Ethical consideration. This study was conducted according to the guidelines laid down in the Declaration of Helsinki, and all procedures involving human subjects were approved by the Institutional Review Board of Ochanomizu University (approval numbers 24–42 and 2013-77) and the Ethics Committee of the Ministry of Health in Rwanda.

The staff of the WVR were trained to obtain informed consent. They obtained it on behalf of Japanese researchers who do not speak local language. Before the survey, a staff of WVR orally explained the details of the survey based on the documents developed by the Japanese researchers. After the explanation, one of the family members, usually the head of the household, provided his/her signature or mark on the consent form. He/she represented all the family members who agreed to participate in the study. Japanese researchers were always present at the scene to answer questions from the participants, if any.

Results

Households. We conducted one-day WFR three times for 10 households, twice for 1 household, and once for 21 households (that is, 53 household-days).

Three households out of 32 households were extended family. The average number of family members and children in a household were 5.3 and 3.5, respectively. Almost all households depended on farming, but three households out of 32 (9.4%) ran small grocery stores in front of/near their houses.

Participants. The WFRs were collected from the household members aged 1–69 years. Household members aged more than 69 years were not included in the sample. Therefore, the oldest adult was 69 years old (Table 1).

The total number of participants in the WFRs was 162, but the duration of the WFRs differed by participants (Table 2). We conducted three-day, two-day, and one-day WFRs for 39 (24.1%), 20 (12.3%), and 103 (63.6%) participants, respectively. We collected a total of 260 WFRs from 162 participants.

Dietary patterns revealed by WFRs. It was not the habit for all members of the household to eat from the same dish. They ate from an individual dish. While 47 of 53 household-days (83.0%) cooked and consumed two or three meals per day, three household-days (5.7%) cooked in large quantities at one time for lunch and dinner together to save firewood. Six household-days (11.3%) ate only lunch.

Twenty-three children aged 1–15 years ate snacks between meals. Cassava, biscuits, sugarcane, porridge, boiled sweet potato, mandazi (fried bread), agatogo (a Rwandan dish mentioned later), boiled beans, carrot, tomato, sweet banana, papaya, and avocado were consumed as snacks.

Rwandan diet was highly dependent on carbohydrates. The WFRs revealed that 77.7% of dietary energy came from carbohydrate and only 9.4% was provided by protein.

Thirty-six household-days (67.3%) drank a cup of porridge for breakfast. Ingredients of porridge were only flour and hot water. About half of the 32 households used mixed flour for making porridge, while others used only maize flour.

Every household consumed agatogo at least once per day. Agatogo is a simmered dish with green banana or potato. They also had soup/sauce about five to six times per week. It was served with starchy staple foods such as umutsima (made from maize flour), ubugari (made from cassava flour), boiled potatoes, green bananas, or rice.

A total of 26 food items, including single food items and mixed dishes, were observed in the WFRs.

Food list of FFQ. Before we selected food items in the FFQ, mixed dishes observed in the WFRs were combined into one group or classified into several types according to the

Table 1. Mean age of participants by age and sex groups.

	1–4 YEARS		5–17 YEARS		18–69 YEARS		TOTAL	
	MALE (n = 7)	FEMALE (n = 11)	MALE (n = 33)	FEMALE (n = 32)	MALE (n = 30)	FEMALE (n = 49)	MALE (N = 70)	FEMALE (N = 92)
Mean	3.3	2.9	9.3	10.3	39.7	33.8	21.4	21.2
SD	1.0	1.1	3.6	3.8	14.4	12.5	17.0	16.7
Min	2.0	1.0	5.0	5.0	18.0	18.0	2.0	1.0
Max	4.0	4.0	17.0	17.0	69.0	64.0	69.0	64.0

Table 2. Number of participants by age and sex groups.

	1–4 YEARS		5–17 YEARS		18–69 YEARS		TOTAL	
	n	%	n	%	n	%	N	%
3-day WFRs								
Male	**2**	11.1	**7**	10.8	**9**	11.4	**39**	24.1
Female	**5**	27.8	**5**	7.7	**11**	13.9		
2-day WFRs								
Male	**1**	5.6	**6**	9.2	**3**	3.8	**20**	12.3
Female	**1**	5.6	**6**	9.2	**3**	3.8		
1-day WFR								
Male	**4**	22.2	**20**	30.8	**18**	22.8	**103**	63.6
Female	**5**	27.8	**21**	32.3	**35**	44.3		
Total	**18**	100.0	**65**	100.0	**79**	100.0	**162***	100.0

Note: *(3-day WFRs × 39) + (2-day WFRs × 20) + (1-day WFR × 103) = 260 WFRs from 162 participants.
Abbreviation: WFR, weighed food record.

inclusion/exclusion of certain ingredients that altered their nutrient composition (Table 3). We divided porridge into two types: porridge with maize flour and mixed flour. Since the mixed flour contains soy powder, protein content in porridge with mixed flour was higher than that with maize flour. Agatogo was also divided into two groups: agatogo with animal food or boiled beans and that without them. We combined soup and sauce into one food group since recipes and ingredients of soup were almost the same as those of sauce (sauce contains less water than soup), and then, we categorized soup/sauce into three types: those "with animal food (with/without boiled beans)", "with beans (without animal food)", and "without animal food and boiled beans". Milk and tea were defined as "milk/tea with milk and sugar" because Rwandans not only consume milk as it is but also add it into tea with sugar.

Eighteen items were selected through four steps shown in Figure 4. First, we combined boiled banana, cassava, and sweet potato in one group because these items have similar nutrient contents and were consumed along with soup. Second, six items (boiled beans, carrot, fried banana, orange, papaya, and tomato) were excluded since they were consumed by less than two participants. Third, biscuits and sugarcane were excluded since their portion size contained less than 100 kcal of energy. Fourth, egg and commercial beverages (soda, cola, and fruit juice) were added since they were commonly sold at stores in the study areas and contain high protein and energy, respectively. Their consumption frequencies varied largely by individuals because they were expensive and only occasionally consumed. Although they were not eaten by any participants during the WFRs, we added them to the food list in order to differentiate individuals by their intake.

Consequently, we developed an 18-item FFQ. Tables 4 and 5 show the portion size by three adult age groups (18–29, 30–49, and 50–69 years) and whole sample aged 18–69 years. No significant difference was observed between the age groups, and this may justify treating them as one age group.

Table 3. Energy and nutrient contents in median portion size for 18- to 69-year-old males by different ingredients.

	ENERGY (kcal)	PROTEIN (g)	IRON (mg)	VITAMIN A (µgRE)
Porridge (per 493.5 g)				
Porridge with maize flour	210	3.9	1.1	5.3
Porridge with mixed flour	219	5.9	1.5	4.2
Agatogo (per 807.0 g)				
Agatogo with animal food or beans	785	17.8	5.6	328
Agatogo without animal food and beans	712	12.8	4.5	315
Soup/sauce (per 234.0 g)				
Soup/sauce with animal food	351	14.0	2.4	173
Soup/sauce with beans	196	10.7	3.0	148
Soup/sauce without animal food and beans	193	6.9	1.5	143

Abbreviation: RE, retinol equivalent.

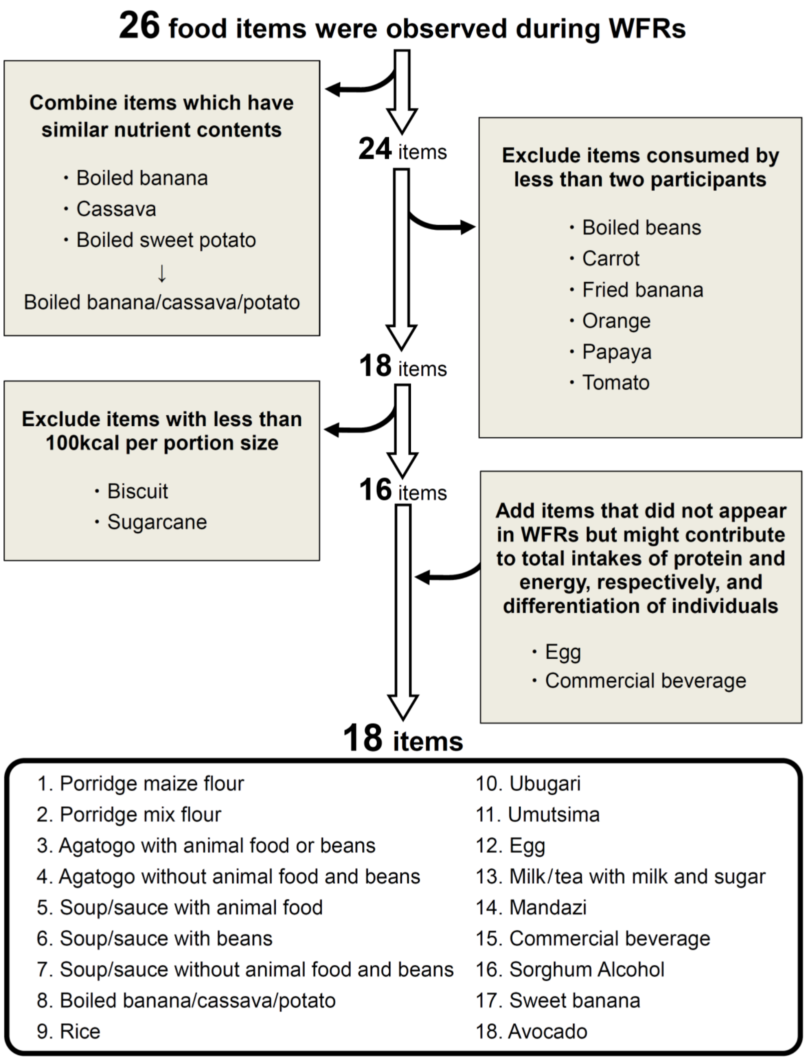

Figure 4. Selection of food items listed in food frequency questionnaire.

Percent contribution of the 16 items other than egg and commercial beverage to energy, protein, iron, and vitamin A intakes are shown in Table 6. Cumulative contribution to the total intakes of energy and nutrients reached nearly 100% and "agatogo with beans" accounted for a considerable percentage of energy and nutrient intakes.

Relative validity of FFQ. Table 7 presents Pearson's correlation coefficients for energy and nutrient intakes estimated from the FFQ and the three-day WFRs. The crude correlation coefficients between the two methods varied from −0.09 (vitamin A) to 0.58 (protein) for the total sample. After adjustment for energy intake, correlation coefficient for iron increased from 0.50 to 0.68. Conversely, correlation coefficient for protein decreased and became insignificant. When the sample was divided by sex, most crude correlation coefficients were not significant. However, energy adjustment improved correlation coefficients for iron.

Cross-classification of the participants according to energy and nutrient intakes estimated from the two methods is shown in Table 8. For protein and iron, 58.8% of the participants were classified into the same tertile. For energy and vitamin A, about 50% of the participants were classified into the same tertile.

Discussion

Dietary patterns. Results from the WFRs revealed that rural Rwandan diets were characterized by a limited variety. The total number of food items observed during the WFRs was as few as 26. Their diets were highly dependent on starchy foods. Similar dietary patterns have been reported previously among rural populations in developing countries including Sub-Saharan Africa.[27]

Our participants ate agatogo at least once per day. "Agatogo with beans" gave the highest contribution to energy and nutrient intakes (Table 6). Since it contained dodo (green leafy vegetable) and beans in addition to a large amount of green banana, it provided high energy and nutrients.

Development of FFQ. In this study, WFRs were not the only dietary source to assemble the food list. Eggs and commercial beverages were not observed in the WFRs, but

Table 4. Median portion sizes of males by adult age groups.

FOOD ITEMS LISTED IN FFQ	18–29 YEARS		30–49 YEARS		50–69 YEARS		TOTAL (18–69 YEARS)			
	n	MEDIAN* (g)	n	MEDIAN* (g)	n	MEDIAN* (g)	N	MEDIAN (g)	P_{25} (g)	P_{75} (g)
Porridge										
Maize flour	8	466.0	5	431.0	2	466.0	15	466.0	358.5	480.0
Mixed flour	1	95.0	10	728.5	4	544.0	15	650.0	517.5	797.5
Agatogo										
With animal food or beans	11	781.0	28	852.0	4	544.5	43	799.0	549.0	1,011.0
Without animal food and beans	1	462.0	3	859.0	3	862.0	7	859.0	639.5	880.0
Soup/sauce										
With animal food (with/without beans)	3	238.0	5	214.0	1	234.0	9	218.0	212.0	238.0
With beans (without animal food)	6	247.5	10	195.5	5	219.0	21	219.0	172.0	260.0
Without animal food and beans	1	246.0	3	292.0	1	401.0	5	292.0	246.0	387.0
Boiled banana/cassava/potato	3	566.0	5	268.0	4	581.0	12	519.0	252.8	598.0
Rice	3	339.0	5	556.0	0	–	8	536.0	362.3	650.3
Ubugari (cassava)	3	289.0	7	654.0	2	449.0	12	449.0	253.8	702.0
Umutsima (maize)	1	280.0	1	232.0	1	422.0	3	280.0	256.0	351.0
Egg	0	–	0	–	0	–	0	(50.0)	–	–
Milk/tea with milk and sugar	1	484.0	1	834.0	0	–	2	659.0	571.5	746.5
Mandazi	1	20.0	1	50.0	0	–	2	35.0	27.5	42.5
Commercial beverage	0	–	0	–	0	–	0	(200.0)	–	–
Sorghum alcohol	0	–	1	1,112.0	1	572.0	2	842.0	707.0	977.0
Sweet banana	0	–	1	120.0	0	–	1	120.0	–	–
Avocado	0	–	2	35.5	0	–	2	35.5	34.3	36.8

Notes: *Kruskal–Wallis test was used to determine whether the median portion size was different among the three adult age groups (18–29, 30–49, and 50–69 years). Mann–Whitney's *U* test was used when portion size data were available only for the two age groups. No significant difference was observed between the groups for any food items.
Abbreviations: P_{25}, 25th percentile; P_{75}, 75th percentile.

we added them into the food list since these two items were commonly sold at stores in the study areas. By using two different dietary sources, the food list in our FFQ covers almost all food items generally consumed by the villagers in the study areas.

Some FFQs were developed through two steps: percent contribution to energy and nutrient intakes and stepwise multiple regression analysis.[28–30] On the other hand, our FFQ was developed by using only percent contribution to energy and nutrient intakes. Stepwise multiple regression analysis was used in order to select food items that contributed to a cumulative 90% of the variance in energy. However, our FFQ's cumulative contributions to the total intakes of energy, protein, iron, and vitamin A reached nearly 100% due to the limited variety of foods/recipes consumed there. Therefore, we did not have to use stepwise multiple regression analysis.

According to previous studies with African people, the number of food items on FFQ ranged from 69 to 164.[4,31–34] Compared to them, our FFQ's food list of 18 food items is very short. It makes our FFQ easy to administer. It takes approximately five minutes to complete.

Relative validity of FFQ. Moderate to high positive correlations were found for crude intakes of energy, protein, and iron for the whole sample. After adjustment for energy intake, however, correlation coefficient for protein intake decreased and became insignificant. This phenomenon was observed in other studies.[4,35,36] It is said that this occurs when validity is related more to systematic errors of over-/underestimation of specific foods than to energy intake.[37] Protein intake is especially susceptible to over-/underestimation because its content in food is larger than that of micronutrients. When the sample was divided by sex, most correlation coefficients (both crude and energy adjusted) were not statistically significant except for those of energy-adjusted iron intake. This is likely due to lower statistical power in the subsample compared to the whole sample.

Our results were similar to other studies with African people. For example, our crude correlation coefficient for energy (0.57) was similar to the values of 0.51 and 0.55 reported by Jackson et al.[4,31] Other researchers reported smaller values that varied from 0.31 to 0.44.[32–34] Our crude correlation coefficient for protein (0.58) and energy-adjusted correlation coefficient for iron (0.68) were the highest among other studies.[31–34]

Table 5. Median portion sizes of females by adult age groups.

FOOD ITEMS LISTED IN FFQ	18–29 YEARS		30–49 YEARS		50–69 YEARS		TOTAL (18–69 YEARS)			
	n	MEDIAN* (g)	n	MEDIAN* (g)	n	MEDIAN* (g)	N	MEDIAN (g)	P_{25} (g)	P_{75} (g)
Porridge										
Maize flour	**9**	473.0	**12**	436.5	**2**	454.5	**23**	450.0	382.0	479.0
Mixed flour	**11**	486.0	**14**	450.0	**2**	815.0	**27**	480.0	432.5	666.5
Agatogo										
With animal food or beans	**28**	675.5	**29**	692.0	**7**	666.0	**64**	688.5	501.3	840.5
Without animal food and beans	**8**	589.5	**4**	710.0	**3**	646.0	**15**	646.0	572.0	776.0
Soup/sauce										
With animal food (with/without beans)	**5**	170.0	**6**	174.0	**0**	–	**11**	170.0	164.0	192.5
With beans (without animal food)	**9**	211.0	**11**	173.0	**5**	212.0	**25**	184.0	167.0	230.0
Without animal food and beans	**3**	171.0	**6**	159.5	**0**	–	**9**	171.0	140.0	184.0
Boiled banana/cassava/potato	**4**	265.0	**9**	264.0	**3**	379.0	**16**	280.5	234.0	379.3
Rice	**10**	562.0	**2**	371.0	**0**	–	**12**	491.0	410.3	665.5
Ubugari (cassava)	**2**	216.0	**8**	369.0	**1**	498.0	**11**	303.0	184.5	496.5
Umutsima (maize)	**2**	361.0	**3**	306.0	**1**	260.0	**6**	283.0	224.8	381.0
Egg	**0**	–	**0**	–	**0**	–	**0**	(50.0)	–	–
Milk/tea with milk and sugar	**3**	405.0	**1**	608.0	**1**	427.0	**5**	427.0	405.0	486.0
Mandazi	**2**	35.0	**0**	–	**0**	–	**2**	35.0	27.5	42.5
Commercial beverage	**0**	–	**0**	–	**0**	–	**0**	(200.0)	–	–
Sorghum alcohol	**0**	–	**0**	–	**0**	–	**0**	(842.0)	–	–
Sweet banana	**1**	93.0	**1**	98.0	**0**	–	**2**	95.5	94.3	96.8
Avocado	**2**	97.5	**3**	31.0	**0**	–	**5**	88.0	31.0	107.0

Notes: *Kruskal–Wallis test was used to determine whether the median portion size was different among the three adult age groups (18–29, 30–49, and 50–69 years). Mann–Whitney's *U* test was used when portion size data were available only for the two age groups. No significant difference was observed between the groups for any food items.
Abbreviations: P_{25}, 25th percentile; P_{75}, 75th percentile.

For vitamin A, crude and energy-adjusted correlation coefficients were not statistically significant. Low validity or no significance for vitamin A is not unusual, and it has been observed in other studies.[4,32] This may have occurred for the following reason in the present study. Our FFQ is dish based since it is easy to answer for male participants who do not cook for themselves. When we calculate energy and nutrient intakes of mixed dishes listed on the FFQ, we used average recipe data from the WFRs. However, the amount and kinds of ingredients in mixed dishes varied by households. Using average recipe data makes it difficult to identify the between-individual variation in vitamin A intake since this nutrient is contained in a large amount in particular foods, and its content largely varies by inclusion/exclusion of certain ingredients. For example, among households, the vitamin A content in agatogo varied from 0 to 176 µgRE per 100 g.

In epidemiological studies, correct classification of individuals according to their energy and nutrient intakes is crucial.[38] Table 8 shows that 47.1%–58.8% of participants were classified in the same tertile and 5.9%–17.6% of them were classified into the opposite tertile. There are some studies that used classification into tertile in the same manner. Our agreement level was similar to one study,[39] but higher than that of another.[40]

Limitations.

Sampling. Only the households that allowed us to stay all day long for the direct-observed WFR could be included in the sample. Due to the nature of the survey, we used convenience sampling. It may cause a sampling bias.

Recruiting more than two participants from the same household is potentially problematic since the 32 households we visited could not cover between-household variation in cooking.

In our direct-observed WFR, one Japanese researcher and one WVR staff stationed in one house all day long and directly observed, weighed, and recorded what they consumed on the day. It was a very manpower- and time-consuming method, and therefore, we could only visit the small number of households in the limited field survey period of one to three weeks per occasion. Self-administered WFR was not an option since it could not provide valid data unless participants' high motivation and literacy are guaranteed. Since there was not a sufficient number of skilled local staff to help the survey in rural area, we could not increase the number of research teams. In order to increase the number of participants under

Table 6. Percent contribution of 16 food items observed in weighed food record to total intakes of energy and nutrients.

ENERGY		PROTEIN	
Food items	**(%)**	**Food items**	**(%)**
1. Agatogo with beans	44.1	1. Agatogo with beans	42.7
2. Agatogo without beans	8.8	2. Soup with beans	11.7
3. Boiled banana, cassava and sweet potato	8.7	3. Porridge mixed flour	8.3
4. Porridge mixed flour	7.7	4. Agatogo without beans	7.7
5. Ubugari	5.8	5. Boiled banana, cassava and sweet potato	6.4
6. Soup with beans	5.5	6. Soup with animal food	4.6
7. Rice	5.3	7. Porridge maize flour	4.3
8. Porridge maize flour	4.9	8. Rice	4.2
9. Umutsima	2.4	9. Soup without animal food and beans	2.7
10. Soup with animal food	2.1	10. Ubugari	2.5
11. Soup without animal food and beans	1.7	11. Umutsima	1.9
12. Milk/tea with milk and sugar	1.0	12. Milk/tea with milk and sugar	1.5
13. Mandazi	0.4	13. Sorghum alcohol	0.4
14. Avocado	0.3	14. Avocado	0.2
15. Sweet banana	0.3	15. Mandazi	0.2
16. Sorghum alcohol	0.3	16. Sweet banana	0.2
SUM	**99.3**	**SUM**	**99.5**
IRON		**VITAMIN A**	
Food items	**(%)**	**Food items**	**(%)**
1. Agatogo with beans	45.0	1. Agatogo with beans	52.3
2. Soup with beans	10.6	2. Soup with beans	15.2
3. Agatogo without beans	8.9	3. Agatogo without beans	12.0
4. Porridge mixed flour	7.5	4. Soup with animal food	7.3
5. Boiled banana, cassava and sweet potato	7.4	5. Boiled banana, cassava and sweet potato	4.9
6. Ubugari	4.5	6. Soup without animal food and beans	4.0
7. Porridge maize flour	4.2	7. Milk/tea with milk and sugar	1.1
8. Soup with animal food	3.2	8. Porridge mix flour	1.0
9. Rice	2.5	9. Ubugari	0.5
10. Umutsima	2.1	10. Rice	0.5
11. Soup without animal food and beans	2.0	11. Porridge maize flour	0.5
12. Sorghum alcohol	0.3	12. Avocado	0.1
13. Avocado	0.2	13. Sweet banana	0.0
14. Sweet banana	0.2	14. Mandazi	0.0
15. Mandazi	0.2	15. Sorghum alcohol	0.0
16. Milk/tea with milk and sugar	0.0	16. Umutsima	0.0
SUM	**98.9**	**SUM**	**99.5**

these constraints, more than two members from the same household were selected.

Sample size. Since the study was conducted on a few household of two sites only, the findings may not be representative of the country and even of the rural areas.

Some suggest that a minimum number of 50 or preferably 100 participants are necessary to assess the absolute agreement.[7,8] Our small sample size with 17 adults in validation study is a serious drawback.

However, our data had higher accuracy of measuring and recording compared to self-administered WFR where participants self-report their intake. And it was free from recall bias and errors in portion size estimation owing to direct observation by the qualified trained researchers. It should be noted that some validation studies with small sample size of 23, 19 and 15 adults were also published.[35,41,42]

Direct-observed WFR. The WFR is a prospective means of assessing dietary intake, and this is considered superior

Table 7. Pearson's correlation coefficients for energy and nutrient intakes estimated from food frequency questionnaire and three-day weighed food records.

NUTRIENTS*	TOTAL (N = 17)		MALE (n = 8)		FEMALE (n = 9)	
	r	*P*-VALUE	*r*	*P*-VALUE	*r*	*P*-VALUE
Crude						
Energy (kcal)	0.57	0.02	0.17	0.70	0.49	0.18
Protein (g)	0.58	0.02	0.39	0.34	0.47	0.20
Vitamin A (µgRE)	−0.09	0.72	−0.84	0.01	0.03	0.93
Iron (mg)	0.50	0.04	0.06	0.89	0.44	0.23
Energy adjustment						
Protein (g)	0.32	0.21	0.59	0.12	0.08	0.84
Vitamin A (µgRE)	−0.19	0.46	−0.36	0.39	0.13	0.74
Iron (mg)	0.68	0.002	0.72	0.05	0.77	0.02

Note: *All variables were log-transformed before analysis for improvement of the normality.
Abbreviation: RE, retinol equivalent.

to retrospective methods including dietary recall. Although participants may simplify or skip meal to reduce burden of weighing and recording in self-reported WFR, direct-observed WFR does not burden them. On the other hand, observer bias may occur in the latter. In order to reduce the bias, the procedure of the WFR was standardized by manual and training.

There is a possibility that the participants modified their diet since some participants, especially females, might feel uncomfortable to eat in front of us. Another possible bias could be caused by the fact that the foods and particularly drinks consumed away from home may not have been reported in full.

Another flaw is that we conducted the WFRs on weekdays only, since local staff could not work on weekends for religious reason. As a result, this validation study did not take into account the differences between meals during weekdays and weekends. Although it seemed that variation in food intake between weekdays and weekends in developing countries is not as large as in developed countries, this missing information could skew the data.

Finally, the number of times that the WFRs were conducted in each season was different between the two sectors. In Rukara sector, data were collected in two rainy seasons and one dry season, while in Mwiri sector, data collection was conducted during two dry seasons and one rainy season. Owing to the seasonal variation in food availability, this discrepancy in data collection times may have potentially misrepresented both the type and amount of food consumed.

Table 8. Cross-classification of participants according to energy and nutrient intakes estimated from food frequency questionnaire and three-day weighed food records.

NUTRIENTS	TOTAL (N = 17)		
	SAME TERTILE (%)	ADJACENT TERTILE (%)	OPPOSITE TERTILE (%)
Energy (kcal)	47.1	47.1	5.9
Protein (g)	58.8	35.3	5.9
Vitamin A (µgRE)	47.1	35.3	17.6
Iron (mg)	58.8	35.3	5.9

Abbreviation: RE, retinol equivalent.

Conclusion

Since diets in the eastern rural area of Rwanda had a limited variety, our 18-item FFQ could cover the variation in food intake. The FFQ showed moderate validity for energy and high validity for iron. This tool could be used to rank Rwandan adults correctly according to their energy and iron intakes in a simple manner. For true validation of the FFQ, this study needs to be repeated in a more statistical and comprehensive manner with a larger population including children.

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Author Contributions

Conceived and designed the experiments: NS, MS, TM, HI, and HM. Analyzed the data: AY, NS, YA, YC, MS, and HM. Wrote the first draft of the manuscript: AY and YA. Contributed to the writing of the manuscript: AY, NS, YA, MS, and HM. Agreed with manuscript results and conclusions: AY, NS, YA, YC, MS, CM, TM, HI, TS, and HM. Jointly developed the structure and arguments for the paper: AY, NS, MS, and HM. Made critical revisions and approved the final version: NS, MS, and HM. All the authors reviewed and approved the final manuscript.

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