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Food insecurity is associated with food consumption patterns and anthropometric measures but not serum micronutrient levels in adults in rural Tanzania

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Abstract

Objective: The purpose of the present paper is to assess the relationship between food insecurity and food consumption patterns, anthropometric measures and serum micronutrient levels in rural Kilimanjaro, Tanzania.
Design: A population-based cross-sectional study was carried out between March and May of 2005.
Setting: Rural Kilimanjaro, Tanzania.
Subjects: Analysis was restricted to 1014 adults aged 15–44 years with children and complete data.
Results: A large majority of the participants (91 %) reported some kind of food insecurity. Food insecurity was significantly associated with age, marital status and occupation. Participants reporting food insecurity were significantly less likely to frequently consume animal products, fruits and vegetables compared with participants categorized as food secure. Women categorized as experiencing individual food insecurity had a larger waist circumference than food-secure women ($P = 0{\cdot}026$) while the mean BMI of women appeared to decline if they had a child who was food insecure ($P = 0{\cdot}038$). There were no observed differences in serum micronutrient levels by food insecurity status.
Conclusions: Food insecurity is highly prevalent and associated with food consumption patterns, waist circumference and BMI of women in rural Tanzania. Further studies should apply self-report measures in assessing food insecurity to larger and more diversified populations.

Keywords
Food insecurity
Eating pattern
Micronutrients
Anthropometry
Rural Tanzania

Food insecurity is a public health concern in both developed and developing countries, affecting the urban and rural poor. Food security is defined by the World Food Summit as a state where 'all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life'[1]. Globally it is estimated that about 854 million people are food insecure, with 820 million of these living in developing countries[2].

Poor dietary intake is described as an integral characteristic of food insecurity that may result in poor nutritional state and quality of life[3]. Recent methodological advances in the measurement of food insecurity have allowed exploration of the influence of food insecurity on dietary consumption of adults in both developed[4–7] and developing countries[8–10]. These studies have revealed that food insecurity is associated with lower intakes of meat and dairy products, fruits and vegetables, as well as lower consumption of nutrients that may result in poor nutritional status and health[4,5,7,8,10]. These findings have forged a path for dietary data to be used in validation of questionnaire-based food insecurity measures in developing countries[11,12].

Dietary patterns from most developing countries and in particular African countries are described as monotonous, comprising foods low in energy, few animal products and fruits and vegetables[8,13–16]. These patterns are increasingly being named responsible for the high rates of malnutrition and micronutrient deficiencies observed in these countries, although other non-food related factors may also partly explain the magnitude observed[17]. In light of the predicted increase in the magnitude of food insecurity in East Africa[2] and the latest crises in food

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prices, there is a need for simple instruments that can assess dietary patterns accurately, timely and cost-effectively. The use of questionnaire-based food insecurity instruments may fill in this crucial gap.

Using a recently adapted and validated Radimer/Cornell food insecurity measure for use in rural Tanzania[18], we hypothesized that food insecurity (assessed by a questionnaire-based instrument) may predict decreased dietary intake and result in a continuum of negative outcomes, namely micronutrient deficiencies and poor nutritional status.

Methods

Study area and subjects

The study was conducted in Oria village, Moshi Rural district. The village is located at the foot of Mount Kilimanjaro, a few kilometres from the Tanzania–Kenya border and about 30 km south of the regional administrative capital, Moshi. The population mainly consists of peasants who grow maize, paddy and vegetables; petty businessmen selling agricultural products and fish; and a few employed individuals. The village has a weekly market selling a variety of commodities from fruits and vegetables to clothes and shoes. It is used by local and neighbouring villagers and by business people from Moshi town. A detailed description of the study area is given elsewhere[19].

Study design and survey procedure

A cross-sectional study was carried out in Oria village between March and May of 2005. Before onset of the study, house-to-house registration of all eligible participants (aged 15–44 years with a permanent address in the village) was performed by trained research assistants with support from village and hamlet leaders. A total of 2093 individuals were listed and invited to participate. Consenting individuals were interviewed by the research team in or near their homes. The ethical committees of the Tanzania Ministry of Health and the Norwegian Committee for Medical Research reviewed and approved the study protocol.

Questionnaire data

All participants responded to questions on demographic characteristics, food insecurity items and a short FFQ. Food insecurity was assessed using an adapted version of the Radimer/Cornell food insecurity scale whose validity and reliability have been established in this setting[18]. We defined a participant as 'food secure' if they responded 'never' to all of the Radimer/Cornell items; as 'individual food insecure' if they responded 'sometimes' or 'always' to items on anxiety to food depletion, monotony in diet or decreased individual food intake; and 'child food insecure' if they responded 'sometimes' or 'always' to any of the child items.

Dietary assessment

Dietary intake was assessed by using a thirty-eight-item FFQ. Participants were asked on average how often in the past month they had consumed each food item (e.g. meat/eggs/oranges/amaranth leaves, etc.). There were five response categories: 'every day', 'several times a week', 'once a week', 'once or twice a month' and 'less than once a month/rarely/never'. The FFQ was pre-tested with a convenience sample of 150 and has been previously used in this study area[20]. To ease analysis, the food items were condensed into eight simpler food group categories. A summary measure of frequent consumers was determined as eaten 'several times weekly' for fruits and vegetables and 'at least weekly' for animal products. This categorization has been used by other studies[8].

Anthropometric measures

Height was measured to the nearest 0·1 cm using locally made portable devices equipped with height gauges and weight was measured using calibrated portable electronic scales to the nearest 0·1 kg with participants wearing light clothing and no shoes. Waist and hip circumference was measured by trained research assistants (waist measured at the level of the umbilicus and hip measured horizontally at the level of the greatest lateral extension of the hips) with participants standing, using non-stretchable tape measures; and used to construct waist:hip ratio (WHR) (cm/cm). Measurements were conducted in duplicate and an average value was used for the analysis. BMI was calculated as kg/m^2 and classified as proposed by WHO[21]. Participants were classified as underweight (BMI < 18·5 kg/m^2), normal weight (BMI = 18·5–24·9 kg/m^2), overweight (BMI = 25·0–29·9 kg/m^2) or obese (BMI ≥ 30·0 kg/m^2). Central obesity was defined as a WHR of ≥0·85 for women and ≥0·95 for men.

Serum micronutrients

Blood was drawn from the antecubital vein of each participant into a 5 ml Vacutainer tube wrapped with black tape. The blood samples were stored in insulated cool boxes for transportation to the Kilimanjaro Christian Medical Hospital laboratory. The blood samples were centrifuged at 2000 rpm for 15 min at room temperature within 8–10 h of collection. The sera were then separated into Nunc tubes also wrapped with black tape and labelled with sample number. The plasma samples were subsequently stored in a freezer at −20°C and flown to Norway for analysis by VITAS AS laboratories. Serum retinol concentration was determined by HPLC and serum ferritin was measured by ELISA. Iron stores were characterized on the basis of serum ferritin concentration as depleted when <15 μg/l and vitamin A status was characterized as deficient if serum retinol concentration was <0·70 μmol/l.

Statistical analysis

Data were analysed using the SPSS for Windows statistical software package version 14·0 (SPSS Inc., Chicago, IL, USA). Descriptive statistics were used to depict overall distribution of the variables. ANOVA was used to describe means and standard deviations for continuous variables according to food insecurity status. Prevalences of categorical variables were evaluated with contingency tables, expressed as percentages, and accompanied by the χ^2 test for differences in proportion. We examined the outcome food insecurity status in relation to demographic characteristics using three categories (food secure, food insecure at individual level and food insecure at child level). In logistic regression models two dummy variables were created from food insecurity status, food insecure at individual level and food insecure at child level; the category food secure was used as the reference. We evaluated the association between food insecurity status and food consumption patterns using a summary measure where one term for frequent consumption was used. We employed analysis of covariance to examine whether anthropometric measures differed by food insecurity status controlling for potential confounders. Since sex contributes to the variation observed in both food insecurity status and anthropometric measures, we examined for possible differences among men and women separately. Finally, we examined the association between food insecurity status and serum micronutrient levels. In our multivariable logistic models we considered age, sex, marital status, education and occupation as potential confounders. Our results are given as odds ratios and their 95 % confidence intervals. Significance was set at $P < 0{\cdot}05$.

Results

A total of 1528 (73 %) adults aged between 15 and 44 years participated in the survey. Of these, 452 (30 %) did not have children and sixty-two (4 %) had missing data for either one or more of the food insecurity items or demographic variables. In the analysis presented herein, 1014 adults were included with anthropometric measurements available for 1006 (99 %) subjects. There was no difference in the distribution of demographic characteristics and food insecurity status between participants with and without anthropometric measurements.

Food insecurity and demographic characteristics

Food insecurity was prevalent with 91 % of the subjects reporting some kind of food insecurity (food secure, 9 %; individual food insecure, 37 %; child food insecure, 54 %). Table 1 shows the prevalence and odds ratio of food insecurity status according to demographic characteristics. Food insecurity was associated with age, marital status and occupation. The adjusted odds ratio (AOR) for food insecurity at the individual level, compared with food secure, for age groups 21–30 years, 31–40 years and ≥41 years respectively, was 1·23 (95 % CI 0·67, 2·24), 2·57 (95 % CI 1·39, 4·75) and 6·10 (95 % CI 3·07, 12·11). Married participants were less likely to report individual food insecurity compared with single participants (AOR = 0·36; 95 % CI 0·21, 0·59). Further analysis revealed that this association was limited to males (AOR = 0·07; 95 % CI 0·01, 0·26).

Table 1 Prevalence and odds ratio of food insecurity status according to sociodemographic characteristics among adults aged 15–44 years with children in rural Kilimanjaro, Tanzania, 2005

		Food secure	Individual-level food insecurity			Child-level food insecurity		
Variable	*n*	%	%	AOR†	95 % CI	%	AOR†	95 % CI
Age group								
<21 years	73	16·4	26·0	1·00	ref	57·5	1·00	ref
21–30 years	423	12·5	26·5	1·23	0·67, 2·24	61·0	1·04	0·61, 1·75
31–40 years	388	5·4	41·2	2·57***	1·39, 4·75	53·4	0·70	0·41, 1·21
≥41 years	130	4·6	62·3	6·10***	3·07, 12·11	33·1	0·29***	0·15, 0·55
Sex								
Men	313	5·8	42·3	1·00	ref	51·8	1·00	ref
Women	701	10·6	34·1	0·84	0·62, 1·14	55·3	1·00	0·75, 1·34
Marital status								
Single	79	7·6	49·4	1·00	ref	43·0	1·00	ref
Married/cohabiting	801	10·1	33·3	0·36***	0·21, 0·59	56·6	2·01***	1·23, 3·27
Separated/divorced/widowed	134	3·7	49·3	0·62	0·33, 1·12	47·0	1·50	0·83, 2·70
Education level								
No education	136	3·7	41·2	1·42	0·75, 2·64	55·1	1·20	0·66, 2·14
Primary	800	9·4	36·4	1·24	0·73, 2·11	54·3	1·04	0·64, 1·69
Secondary+	78	15·4	32·1	1·00	ref	52·6	1·00	ref
Occupation								
Peasant	860	8·7	35·9	0·63*	0·42, 0·92	55·3	1·52*	1·05, 2·18
Others	154	11·0	40·9	1·00	ref	48·1	1·00	ref
Ethnicity								
Chagga	271	8·5	34·3	NS		57·2	NS	
Pare	291	13·1	36·4	NS		50·5	NS	
Others	452	6·9	38·3	NS		54·9	NS	

ref, reference category.
†Odds ratio adjusted for age, sex, marital status, education level and occupation.
Statistical significance: $^{*}P < 0{\cdot}05$, $^{***}P < 0{\cdot}001$.

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Finally, peasants were less likely to report food insecurity at the individual level compared with respondents reporting other occupations (AOR = 0·63; 95 % CI 0·42, 0·92).

Food insecurity at the child level was associated with age, marital status and occupation. In multivariable logistic regression, adults aged ≥41 years were less likely to report child food insecurity than adults aged <21 years (AOR = 0·29; 95 % CI 0·15, 0·55). There was a significant and positive association between food insecurity at child level and marital status (AOR = 2·01; 95 % CI 1·23, 3·27) and being a peasant (AOR = 1·52; 95 % CI 1·05, 2·18).

Food insecurity and food consumption patterns

The distribution and likelihood of food consumption by food insecurity status is depicted in Table 2. There was evidence of a strong and significant negative trend in the prevalence of frequent fruits and vegetables, meat, chicken and eggs consumption and food insecurity status. There was no marked difference in fish consumption across the food insecurity groups.

Food insecurity and anthropometric measures

The mean (SD) anthropometric measurements for the study population were: height 160·0 (8·4) cm; weight 56·6 (9·7) kg; waist circumference 77·3 (11·8) cm; hip circumference 91·3 (11·7) cm; WHR 0·68 (0·18) for men and 0·61 (0·14) for women; and BMI 22·2 (3·7) kg/m^2. The majority of participants were categorized as having normal weight (69 %) followed by overweight (18 %); the rest were underweight (8 %) or obese (5 %). The mean BMI and waist circumference of women varied with food insecurity status. Women categorized as having children experiencing food insecurity had lower mean (SD) BMI values than women who were food secure: 22·3 (3·9) *v*. 23·3 (3·9) kg/m^2 (P = 0·038). Also women experiencing food insecurity at the individual level had higher mean (SD) waist circumference than women reporting food security: 80·1 (10·5) *v*. 78·0 (9·7) cm (P = 0·026). Other anthropometric measures did not differ according to food insecurity status (Table 3). Bivariate analysis showed borderline significance of the percentage of women with

Table 2 Distribution and likelihood of food consumption by food insecurity status among adults aged 15–44 years with children in rural Kilimanjaro, Tanzania, 2005

		Food secure† (*n* 92)	Individual-level food insecurity (*n* 372)			Child-level food insecurity (*n* 550)		
Food consumption pattern	*n*	%	%	AOR‡	95 % CI	%	AOR‡	95 % CI
Whether eaten several times weekly								
Citrus fruits	334	47·8	29·8	0·52***	0·31, 0·84	32·5	0·54*	0·34, 0·85
Non-citrus fruits	901	95·7	86·8	0·26*	0·08, 0·75	89·1	0·34*	0·11, 0·94
Green leafy vegetables	670	78·3	66·7	0·53*	0·30, 0·93	63·6	0·47*	0·27, 0·80
Other vegetables	922	97·8	90·1	0·19*	0·04, 0·82	90·4	0·20*	0·04, 0·85
Whether eaten at least weekly								
Meat	513	87·0	53·5	0·19***	0·09, 0·36	42·5	0·11***	0·06, 0·22
Fish	961	94·6	93·8	0·86	0·30, 2·42	95·5	1·14	0·41, 3·09
Chicken	246	35·9	22·8	0·65	0·38, 1·08	23·3	0·59***	0·36, 0·95
Eggs	453	62·0	39·0	0·48***	0·29, 0·79	45·6	0·56***	0·35, 0·88

†Food secure as the reference category.
‡Odds ratio adjusted for age, sex, marital status, education level and occupation.
Statistical significance: *P < 0·05, ***P < 0·001.

Table 3 Anthropometric characteristics† of study participants by food insecurity status: adults aged 15–44 years with children in rural Kilimanjaro, Tanzania, 2005

	Food secure		Household-level food insecurity		Child-level food insecurity		
Variable	Mean	SD	Mean	SD	Mean	SD	*P* value
Men	*n* 18		*n* 133		*n* 160		
Weight (kg)	58·5	7·3	57·7	7·9	58·3	8·5	0·930
Height (cm)	167·3	5·9	165·9	7·6	166·5	7·1	0·681
BMI (kg/m^2)	20·9	2·5	21·0	2·8	21·0	2·8	0·965
Waist circumference (cm)	76·8	5·2	77·6	8·3	76·2	8·0	0·351
Hip circumference (cm)	88·7	5·1	86·9	9·6	88·0	10·4	0·860
WHR	0·66	0·60	0·68	0·17	0·68	0·18	0·898
Women	*n* 73		*n* 236		*n* 387		
Weight (kg)	57·4	10·5	56·9	10·8	55·1	9·7	0·103
Height (cm)	157·1	6·6	156·7	7·4	157·4	7·4	0·235
BMI (kg/m^2)	23·3	3·9	23·2	4·2	22·3	3·9	0·038*
Waist circumference (cm)	78·0	9·7	80·1	10·5	76·8	12·4	0·026*
Hip circumference (cm)	92·0	12·0	94·6	11·8	92·1	12·3	0·221
WHR	0·63	0·17	0·60	0·08	0·61	0·15	0·073

WHR, waist:hip ratio.
†Adjusted for age, marital status, education level and occupation.
Statistical significance: *P < 0.05.

Table 4 Distribution of BMI and central obesity of study participants according to food insecurity status: adults aged 15–44 years with children in rural Kilimanjaro, Tanzania, 2005

Variable	Food secure (%)	Household-level food insecurity (%)	Child-level food insecurity (%)	*P* value
Men	*n* 18	*n* 133	*n* 160	
BMI category				
<18·5 kg/m^2	11·1	12·8	9·4	
18·5–24·9 kg/m^2	77·8	77·4	79·4	
25·0–29·9 kg/m^2	11·1	9·0	9·4	
≥30·0 kg/m^2	0·0	0·8	1·9	0·934
Central obesity†				
No	100.0	98·5	97·5	
Yes	0·0	1·5	2·5	0·677
Women	*n* 73	*n* 236	*n* 386	
BMI category				
<18·5 kg/m^2	5·5	5·1	7·3	
18·5–24·9 kg/m^2	61·6	59·7	69·2	
25·0–29·9 kg/m^2	23·3	27·1	18·4	
≥30·0 kg/m^2	9·6	8·1	5·2	0·075
Central obesity†				
No	95·7	99·6	97·4	
Yes	4·3	0·4	2·6	0·064

†Central obesity classified as waist:hip ratio ≥0·85 for women and ≥0·95 for men.

central obesity ($P=0·064$), as did BMI categories ($P=0·075$), with food insecurity status (Table 4). Further analysis using regression models did not reveal any significant associations.

Food insecurity and serum micronutrient levels

The mean (SD) serum ferritin level was 58·6 (115·8) μg/l and mean (SD) serum vitamin A level was 1·26 (0·52) μmol/l. Iron depletion was prevalent in 23·5 % (230/979) of the respondents and vitamin A deficiency was observed in 10·7 % (104/971) of the respondents. There was no correlation between food insecurity status and iron depletion or vitamin A deficiency.

Discussion

The present study assessed the association between food insecurity status and food consumption patterns, anthropometric measures and serum micronutrient levels among adults in rural Kilimanjaro, Tanzania. The overall prevalence of food insecurity in this rural area was high. Food insecurity status was associated with selected demographic characteristics at both the individual and child level. These findings are similar to observations from other studies in developed countries[22] as well as developing countries[8–10,23,24]. Contrary to findings from studies conducted in other developing countries[8–10,23,24], we observed no significant association between food insecurity and education. Although the majority of participants reported attending primary school, this has been described as insufficient to reduce poverty[25]. Further, a small number of participants reported having secondary education or higher which limited our statistical power to detect any differences.

We also observed a larger proportion of married men and women reporting children experiencing food insecurity compared with those who were single. In their study in the USA, Hanson *et al.*[26] observed that divorced men reported more food insecurity than never-married men. The disparity in our observation may be due to differences in the tool used to assess food insecurity and categorization of food insecurity. Additionally, differences in the study populations as well as socio-cultural factors may put more pressure on married adults in a Tanzanian context that may lead to more severe food insecurity experiences.

Data obtained on food frequency intake revealed that participants who were food insecure had low intakes of animal products, fruits and vegetables compared with food-secure participants. The low dietary intakes of animal products, fruits and vegetables in food-insecure individuals are consistent with the findings from other studies[8–10,24,27]. The magnitude of the difference in food consumption between food-secure and food-insecure respondents was larger for meat and eggs. This may be because foods of animal origin are generally expensive and unaffordable to the majority of the rural population, while plant sources are less costly[15,28]. Vegetables in Africa are said to play a vital role in food security, particularly for the poor, in both rural and urban settings[13,29]. It is estimated that about 80 % of rural Tanzanians rely on home-grown fruits and vegetables particularly during the lean rainy seasons as a primary food and relish[13,15,30,31]. The magnitude of the difference in fruit and vegetable consumption between food-secure and food-insecure individuals may widen during the dry season as vegetables become scarce and households rely more on markets[11,13].

Fruits and vegetables offer a great source of micronutrients if prepared properly and taken in adequate amounts. The prevalence of both iron depletion and vitamin A deficiency indicates that they were common in the study population. However, there was no difference in the proportion of adults who were either iron depleted

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or vitamin A deficient by food insecurity status. Low serum levels of micronutrients including vitamin A, carotenoids and vitamin E have been described among adults from food-insufficient families in developed countries[32]. Our findings show that a modest proportion of the population consumed fruits and vegetables regularly. The ready availability of leafy green vegetables from home gardens during the rain season may have allowed for most of the micronutrient requirements of the population to be met[31]. However, the lack of correlation between food insecurity status and micronutrient status may be explained by: (i) small variation in the bioavailability of iron and pro-vitamin A in the fruits and vegetables consumed as a result of nutrient loss during preparation[30]; (ii) the cut-off points used were based on acute manifestations of micronutrient deficiencies; (iii) some nutrients such as vitamin A are tightly regulated by the liver and not affected by recent dietary intake; and (iv) some infections can influence serum ferritin levels in the body[33]. More studies are needed to assess food preparation habits of food-secure and food-insecure households and the influence it may have on micronutrient status.

There are plausible biological mechanisms to suggest that food insecurity has negative health outcomes on those experiencing it[3]. Studies assessing the association between food insecurity and nutritional status in both developed[34–36] and developing countries[8,10] have produced conflicting results. Our findings suggest that increased adiposity among women may be associated with food insecurity at the individual level while decreased adiposity among women may be associated with food insecurity at the child level; similar to what other studies have observed[10,11,37]. In light of the prevalence of food insecurity, it is expected that underweight due to a lack of adequate food would be the primary manifestation of food insecurity in this setting; however, nutritional status assessed by anthropometric measures is considered a distal outcome of food insecurity and is not only determined by access to food[11]. The lack of a significant association between food insecurity and anthropometric measures in the multivariable analysis may be because of the time lag between inadequate food intake and observable physical changes. Moreover, anthropometric measures are sensitive to other variables such as infection, sanitation and hygiene[17]. Our study was conducted at the onset of the pre-harvest lean (rainy) season when food shortages and increased energy expenditure from agricultural work had just begun. Thus, physical changes may not have occurred sufficiently to be detected during the survey. Further studies are needed to examine changes in nutritional status that accompany seasonal variation in food insecurity in rural Tanzania.

Limitations of the present study lie in the temporal nature of the data, specifically the fact that food insecurity data were not coincident with data on food consumption, anthropometry and micronutrient status. This raises important questions about cause and effect. Another limitation is the use of a non-validated FFQ to assess dietary patterns. The inherent recall bias associated with the FFQ would make it less likely to correctly describe usual dietary intake. However, allowing for control of factors known to influence under-reporting such as age, sex and education and pre-testing of the FFQ, we believe our results are a fair representation of actual dietary patterns[38]. The strength of the present survey lies in the use of a validated self-report measure of food insecurity, assessing food insecurity at an individual level to allow direct comparison with nutritional outcomes, and inclusion of the whole adult population with a fairly good response proportion.

Conclusion

Our study has shown that food insecurity was highly prevalent and associated with food consumption patterns, waist circumference and BMI of women in rural Tanzania. Further studies should apply self-report measures in assessing food insecurity to larger and more diversified populations.

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References

1. Food and Agriculture Organization of the United Nations (1998) *Rome Declaration on World Food Security. World Food Summit 1996*. Rome: FAO.
2. Food and Agriculture Organization of the United Nations (2006) *The State of Food Insecurity in the World 2006*. Rome: FAO.
3. Campbell CC (1991) Food insecurity: a nutritional outcome or a predictor variable? *J Nutr* **121**, 408–415.

4. Frongillo EA, Olson CM, Rauschenbach BA *et al.* (1997) *Nutrition Consequences of Food Insecurity in a Rural New York State County. Discussion Paper* no. 1120-97. Madison, WI: Institute for Research on Poverty.
5. Olson CM (1999) Nutrition and health outcomes associated with food insecurity and hunger. *J Nutr* **129**, 2S Suppl., 521S–524S.
6. Tarasuk VS & Beaton GH (1999) Women's dietary intakes in the context of household food insecurity. *J Nutr* **129**, 672–679.
7. Tarasuk VS (2001) Household food insecurity with hunger is associated with women's food intakes, health and household circumstances. *J Nutr* **131**, 2670–2676.
8. Gulliford MC, Mahabir D & Rocke B (2003) Food insecurity, food choices, and body mass index in adults: nutrition transition in Trinidad and Tobago. *Int J Epidemiol* **32**, 508–516.
9. Nnakwe N & Yegammia C (2002) Prevalence of food insecurity among households with children in Coimbatore, India. *Nutr Res* **22**, 1009–1016.
10. Shariff ZM & Khor GL (2005) Obesity and household food insecurity: evidence from a sample of rural households in Malaysia. *Eur J Clin Nutr* **59**, 1049–1058.
11. Frongillo EA & Nanama S (2006) Development and validation of an experience-based measure of household food insecurity within and across seasons in Northern Burkina Faso. *J Nutr* **136**, 1409S–1419S.
12. Zalilah MS & Ang M (2001) Assessment of food insecurity among low income households in Kuala Lumpur using the Radimer/Cornell food insecurity instrument – a validation study. *Malays J Nutr* **7**, 15–32.
13. Kinabo J, Mnkeni AP, Nyaruhucha CNM *et al.* (2006) Feeding frequency and nutrient content of foods commonly consumed in the Iringa and Morogoro regions in Tanzania. *Int J Food Sci Nutr* **57**, 9–17.
14. Maruapula S & Chapman-Novakofski K (2007) Health and dietary patterns of the elderly in Botswana. *J Nutr Educ Behav* **39**, 311–319.
15. Mazengo MC, Simell O, Lukumanji A *et al.* (1997) Food consumption in rural and urban Tanzania. *Acta Trop* **68**, 313–326.
16. Tatala S, Svanberg U & Mduma B (1998) Low dietary iron availability is a major cause of anemia: a nutrition survey in the Lindi district of Tanzania. *Am J Clin Nutr* **68**, 171–178.
17. UNICEF (1990) *Strategy for Improved Nutrition of Children and Women in Developing Countries. A UNICEF Policy Review.* New York: UNICEF.
18. Leyna GH, Mmbaga EJ, Mnyika KS *et al.* (2008) Validation of the Radimer/Cornell food insecurity measure in rural Kilimanjaro, Tanzania. *Public Health Nutr* **11**, 684–689.
19. Klouman E, Masenga EJ, Klepp KI *et al.* (1997) HIV and reproductive tract infections in a total village population in rural Kilimanjaro, Tanzania: women at increased risk. *J Acquir Immune Defic Syndr Hum Retrovirol* **14**, 163–168.
20. Ottesen M (2003) Self-perceived food security among school adolescents in a rural area of northern Tanzania. Dissertation, University of Oslo.
21. World Health Organization (1995) *Physical Status: The Use and Interpretation of Anthropometry. Report of a WHO Expert Committee.* Geneva: WHO.
22. Furness BW, Simon PA, Wold CM *et al.* (2004) Prevalence and predictors of food insecurity among low-income households in Los Angeles County. *Public Health Nutr* **7**, 791–794.
23. Isanaka S, Mora-Plazas M, Lopez-Arana S *et al.* (2007) Food insecurity is highly prevalent and predicts underweight but not overweight in adults and school children from Bogotá, Columbia. *J Nutr* **137**, 2747–2755.
24. Zerafati-Shoae N, Omidvar N, Ghazi-Tabatabaie M *et al.* (2007) Is the adapted Radimer/Cornell questionnaire valid to measure food insecurity of urban households in Tehran, Iran? *Public Health Nutr* **10**, 855–861.
25. Wedgewood R (2007) Education and poverty reduction in Tanzania. *Int J Educ Dev* **27**, 383–396.
26. Hanson KL, Sobal J & Frongillo EA (2007) Gender and marital status clarify associations between food insecurity and body weight. *J Nutr* **137**, 1460–1465.
27. Hadley C, Mulder MB & Fitzherbert E (2007) Seasonal food insecurity and perceived social support in rural Tanzania. *Public Health Nutr* **10**, 544–551.
28. Codjia G (2001) Food sources of vitamin A and provitamin A specific to Africa: an FAO perspective. *Food Nutr Bull* **22**, 357–360.
29. Weinberger K & Msuya J (2004) *Indigenous Vegetables in Tanzania: Significance and Prospects. Technical Bulletin* no. 31. Tainan, Taiwan: The World Vegetable Center.
30. Mulokozi G, Lietz G, Svanberg U *et al.* (2003) Plasma levels of retinol, carotenoids, and tocopherols in relation to dietary pattern among pregnant Tanzanian women. *Int J Vitam Nutr Res* **73**, 323–333.
31. Tanner M & Lukmanji Z (1987) Food consumption patterns in a rural Tanzanian community (Kikwawila village, Kilombero District, Morogoro Region) during lean and post-harvest season. *Acta Trop* **44**, 229–244.
32. Dixon LB, Winkleby MA & Radimer KL (2001) Dietary intakes and serum nutrients differ between adults from food-insufficient and food-sufficient families: Third National Health and Nutrition Examination Survey, 1988–1994. *J Nutr* **131**, 1232–1246.
33. Hulthén L, Lindstedt G, Lundberg P-A *et al.* (1998) Effect of a mild infection on serum ferritin concentration – clinical and epidemiological implications. *Eur J Clin Nutr* **52**, 376–379.
34. Townsend MS, Peerson J, Love B *et al.* (2001) Food insecurity is positively related to overweight in women. *J Nutr* **131**, 1738–1745.
35. Whitaker RC & Sarin A (2007) Changes in food security status and change in weight are not associated in urban women with preschool children. *J Nutr* **137**, 2134–2139.
36. Wilde PE & Peterman JN (2006) Individual weight change is associated with household food security status. *J Nutr* **136**, 1395–1400.
37. Chaput JP, Gilbert JA & Tremblay A (2007) Relationship between food insecurity and body composition in Ugandans living in urban Kampala. *J Am Diet Assoc* **107**, 1978–1982.
38. Bedard D, Shatenstein B & Madon S (2004) Underreporting of energy intake from a self-administered food frequency questionnaire completed by adults in Montreal. *Public Health Nutr* **7**, 675–681.