Working Paper on Social-Ecological Resilience Series
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Vulnerability and Resilience of Social-Ecological Systems

RIHN Research Project E-04

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Abstract

Objectives: To reveal the differences of food consumption, physical activity, and travel patterns among contrasting ecological zones and between sexes in the Southern province of Zambia, and to determine whether the mechanism of sustaining nutritional status differs in each zone.

Subjects and Method: A total of 26 men and 30 women aged 18 years and above, living in 3 zones (Lowland, Hillside, and Upland) was examined. Body measurements, a dietary survey using a weighed-food method, a physical activity survey using an accelerometer, and a travel patterns using a portable GPS were conducted.

Results: Although daily energy intake did not differ between the 3 groups for either sex, the proportions of specific food groups contributing to the intakes of energy and macronutrients were significantly different in all zones. Subjects in the Lowland group had a high proportion of fish intake, and those in the Upland group tended to consume a high proportion of roots and tubers. Sex difference in the proportional contribution of food groups for energy and nutrient intakes was identified only in the Lowland group. With regard to physical activity and travel patterns, only traveled radius was significantly different between the 3 groups. The Lowland group had the largest sex difference for energy balance, while the Upland group had the smallest of the 3.

Conclusions: The findings suggest that the factors affecting the energy intake and expenditure in adult villagers differed in every zone. Furthermore, it also showed that each group has different characteristic of lifestyle between the sexes.

Key words: Nutritional Status, Dietary Intake, Physical Activity, Behavioral Pattern, Less Labor-intensive Season for Farming

要約

ザンビア南部州の生態学的に異なる３地域（Lowland、Hillside、Upland）に居住する成人において、農閑期における地域間および男女間の食事・身体活動・行動パターンの違いを検討した。

男女ともに、体格およびエネルギー摂取量において有意な地域差は認められなかった。しかし、食品群別の摂取割合は地域間で異なっており、Lowland 男女では魚類の摂取割合が高く、Upland 男女では根茎類の摂取割合が高いことが明らかとなった。

身体活動はすべての地域の男女で「活動的」と判定された 。男女ともに総エネルギー消費量、身体活動レベル、歩数、総移動距離においては地域差が認められなかったが、行動半径においてのみ有意な地域差がみられ、Hillside 男女が大きかった。

エネルギー出納に地域差は見られなかったものの食事内容と活動内容においては違いがみられたことから、地域ごとにエネルギー出納を適正に保つための戦略が異なることが示唆された。また副業を営む地域では日常の活動に性差が生じやすく、農業に従事する地域では男女類似した活動パターンであるというように、男女の役割分担に地域差があることが示された。

キーワード：体格，栄養摂取，身体活動，行動パターン，農閑期

Contents

Introduction

Food consumption and physical activity are related to seasonal variations in nutritional status. In many developing countries, seasonal variation in food availability influences the nutritional and health conditions of populations (Wandel and Holmboe-Ottesen, 1992). Especially in rural areas, factors that affected nutritional status were not only pre-harvest food shortages, but also high agricultural workloads (Wandel et al. 1992). Although many studies report on the variation of nutritional status, food consumption, and physical activity among agricultural people during the busy farming season (cf. Schofield, 1974; Wandel et al, 1992; Wandel and Holmboe-Ottesen, 1992), only a few studies have investigated these variations specifically during the less labor-intensive season for farming (cf. Yamauchi et al, 2006). Adult villagers actually lost body weight from the post-harvest to the pre-harvest season. (Tanzania: Wandel and Holmboe-Ottesen 1992, Zambia: Yamauchi and Kon 2010), and energy intake decreased after the harvest season (Zambia: Kumar 1988). Thus, knowledge of dietary and physical activity patterns from the post-harvest to the pre-harvest season when body weight is decreasing reveal the causes of the loss of body weight.

The Republic of Zambia is located in a semi-arid tropical zone in the southern part of Africa. It has 2 seasons: a rainy season, which is December to March, and a dry season, April to November. The average elevation within the country is about 1,300 m, and the annual rainfall is about 500–1,500 mm. Traditional farming in rural villages depends on rainfall, and food production is likely to be affected by climatic variation such as drought or heavy rainfall. In the Southern province of Zambia, where drought occurs frequently, it was reported that there were differences in productivity of farm produce (Shimono et al. 2010), meteorology (Kanno et al. 2010), food consumption at the household level (Sakurai et al. 2010), and nutritional status (Yamauchi and Kon 2010) between the upper flat land, middle slope, and lower flat land zones. Therefore, it was expected that the lifestyles such as dietary or physical activity of the people living in each zone were also different from each other.

During the busy farming season: from November to May, most households are farming. While some have a second occupation, which include employment in non-agricultural sectors, others continue farming after harvest of maize. The differences in dietary and physical activity patterns are more likely to be observed during the less labor-intensive season for farming when the diversity of occupation is higher compared to the busy farming season. Furthermore, since gender-specific activities resulting from the division of labor are more easily observed in less labor-intensive season for farming (Yamauchi et al, 2005), the lifestyle differences between the sexes can be more easily observed during that season. In addition, a study reported that variations of nutritional status between the pre-harvest and post-harvest seasons were identified only among women (Wandel and Holmboe-Ottesen, 1992). Thus, the differences of lifestyle can lead to the difference of nutritional status between the sexes. Therefore, identifying the differences of lifestyle such as dietary and physical activity among the contrasting groups in terms of geography and meteorology and between the sexes will show the relationship between body size or composition and lifestyle.

The purpose of this study was to reveal the differences of food consumption, physical activity, and traveled patterns during the less labor-intensive season for farming between the sexes of adults living in 3 contrasting ecological zones in the Southern province of Zambia. Additionally, this study investigated whether the mechanism of maintaining body weight differed in terms of location and sex.

Methods

Study area

The study was conducted in the Sinazongwe district of the Southern province of Zambia (Figure 1). The research area was divided into 3 contrasting ecological zones: upper flat land zone (Upland), which is located on the plateau that continues to Choma city; middle slope zone (Hillside), located on the decline down to Lake Kariba; and lower flat land zone (Lowland), located near Lake Kariba. These zones are located southwest along the causeway from the capital city Lusaka, in the direction of Lake

Kariba before Choma city. Four villages located in these zones: Sianemba and Siameja located in the Lowland; Kanego in the Hillside; and Siachaya in the Upland, were investigated. Table 1 shows the socio-environmental characteristics of each zone.

Design and subjects

Eight households comprised the sample for the Lowland group, and 7 households each comprised the Hillside and Upland groups. A total of 26 men and 30 women aged over 18 years old in the sample households were examined in the period August—September 2010. Village meetings were held to explain the purpose and method of this study to all subjects before beginning the investigation. Informed consent was obtained from the all subjects.

Table 1. Socio-environmental characteristics of the sample zones

	Lowland		Hillside	Upland
	Siameja	Sianemba	Kanego	Siachaya
Total household number*	37	34	16	87
Marriage status**				
monogamy (%)	62.5		42.9	57.1
polygamy (%)	37.5		57.1	42.9
Location	Lower flat land zone		Middle slope zone	Upper flat land zone
Source of drinking water	Hand pump		Stream	Stream
Access by a vehicle	○		—	○

* According to the census (Sakurai 2008)

** Calculated based on the sample households of this study.

(a)

(b)

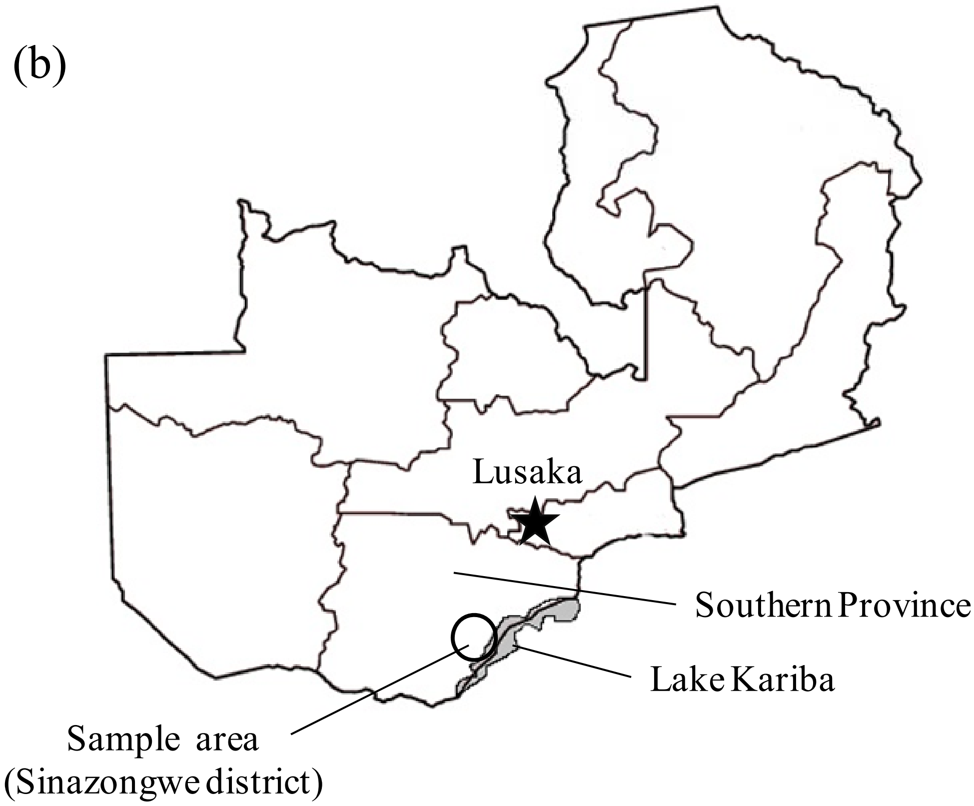

Figure 1. Location of the study area in Zambia

(a) Location of Repubric of Zambia

(b) Study area located in Southern Province of Zambia

Measurements

1) Anthropometry

Height, weight, mid-upper-arm circumference (MUAC), and the triceps and subscapular skinfold thickness were measured following the standard protocol of Weiner and Lourie (1981). Height was measured to the nearest 0.1 cm, using a portable stadiometer (SECA model 213, Germany). Weight was measured to the nearest 0.1 kg using a battery-operated digital scale (TANITA HD-654, Japan). MUAC was measured to the nearest 0.1 cm, using a plastic tape measure (ABBOTT Inser-Tape, Japan). Skinfold thickness was measured to the nearest 1 mm, using a plastic adipometer (ABBOTT, Japan).

Body mass index (BMI; kg/m^2) was calculated as weight (kg)/height (m^2). The sum of the 2-site skinfold thickness was applied to the equation of Durnin and Womersley (1974) to calculate body density, and the equation of Siri (1956) was used to estimate body-fat percentage. Mid-upper-arm muscle area (MUAMA) was calculated using the triceps skinfold thickness and MUAC (Frisancho, 1990).

2) Food Consumption

Food consumption was assessed with weighed-food method. A single day was allocated to each household, and all subjects belonging to same household were examined the same day. To measure meals, I visited sample households before the preparation of breakfast (generally at 07.00 hours) and stayed until subjects had eaten their supper (generally between 20.00 and 21.00 hours). Recall interviews were performed to assess any foods that were consumed prior to the investigator's visit. I visited the household the next day again to interview and assess the foods consumed after I left the household the previous day. The foods that subjects ate outside the home were also estimated by recall interview. Subjects were asked to prepare meals as they usually do.

The weight of food servings and ingredients ranging from 1 to 2,000 g was measured by a digital cooking scale (TANITA KD-402, Japan) to the nearest 1 g. A digital hanging scale (SHINWA 70109, Japan) was used to weigh food in the range of 2 to 20 kg to the nearest 10 g. Food consumption data were converted into quantities of energy and nutritional intakes using the Zambia Food Composition Tables, 4th edition (The National Food and Nutrition Commission of Zambia, 2009). In addition, percentages of energy and macronutrients as derived from 7 food groups (cereals, roots & tubers, fruits & vegetables, beans & nuts, meat & dairy, fish, and others) were calculated.

3) Physical activity

Physical activity was monitored using a uniaxial accelerometer sensor (Lifecorder Ex. Suzuken Co. Ltd, Japan). Subjects attached the device to their waist during 5 consecutive weekdays and data recorded during the middle 3 days were analyzed because the data could not be gotten for 24 hours in 1st day and last day.

Subjects were asked to attach the device just after rising in the morning, to keep it on until retiring for the evening, and to remove it when bathing.

Physical activities were categorized according to the level of activities using a uniaxial accelerometry sensor. Activity levels were categorized into 1 of 11 activity levels (0, 0.5, and 1–9) based on accelerometric signal patterns; the most frequent value per 2 min was recorded.

The total energy expenditure (TEE), which was automatically calculated by the device, was not used. The basal metabolic rate (BMR) based on sex, age, and weight of a subject, was calculated first using the equation of WHO (FAO/WHO/UNU, 2004), then, resting metabolic rate was calculated by 1.2 × BMR (FAO/WHO/UNU, 1985). Estimated metabolic equivalent (MET) values were linked to the activity levels 1–9: 1.8, 2.3, 2.9, 3.6, 4.3, 5.2, 6.1, 7.1, and 8.3 MET, respectively (Kumahara et al. 2004). Activity level of 0.5 was converted into 1.6 MET based on Kumahara's equation: MET $= 0.043x^2 + 0.379X + 1.361$ (x = activity level). Zero activity was considered 0.9 MET according to Ainsworth et al. (2000), because it was defined as the activity level during sleep. Finally, TEE was calculated based on MET values and resting metabolic rate (RMR) value.

4) Travel patterns

Daily travel patterns were investigated using the global positioning system (GPS: Wintec WPL-2000, Taiwan). Subjects wore a portable GPS along with an accelerometer sensor for 3 days corresponding to the middle 3 days of wearing the accelerometer sensor. Location information (track points) were recorded at either 1 point every 20 s or 1 point every 5 m. The latitude, longitude, and elevation of each subject's location, distance from previous point, cumulative distance, movement bearing, and speed of movement were recorded. Traveled tracks were identified using Google Earth software; then the traveled radius, the center of which was the subject's home, was measured.

Data analysis

All data are expressed as means and standard deviation (SD). Regional differences were examined by ANOVA and Tukey's HSD test. Sex differences were examined using the unpaired *t*-test. Difference of contribution of specific food groups to daily energy and nutrient intakes among the 3 groups and between the sexes were examined using the chi-square test. All analyses were performed with the JMP 8.0.2J software package (SAS Japan), with statistical significance set at $P < 0.05$.

Results

Anthropometry

Age and anthropometric measurements are shown in Table 2. Age, body size, and body composition did not differ significantly between the 3 groups for either sex. BMI differences between the sexes were not identified in all groups. MUAMA was higher among men than women ($P < 0.01$), whereas %fat was higher among women than men in all groups ($P < 0.001$). Average BMI in all groups and for both sexes were classified as “normal” ($18.5 \leq \text{BMI} \leq 25.0$) according to WHO criteria (WHO, 2000). The men and women of the Hillside group were characterized as having “lean” physiques because BMI and %fat were the lowest, and MUAMA was the highest of the 3 groups (not significant).

Table 2. Age, body size, and body composition of adults living in 3 contrasting ecological zones of Zambia

a) Male

	Lowland (n = 7)		Hillside (n = 10)		Upland (n = 9)	
	Mean	SD	Mean	SD	Mean	SD
Age (years)	47.3	18.1	36.9	13.1	36.7	18.6
Height (cm)	171.5	4.7	169.3	6.0	165.5	6.6
Weight (kg)	61.1	2.4	58.4	2.0	57.8	2.2
BMI (kg/m^2) [1]	20.7	2.2	20.4	1.5	21.0	1.8
%fat (%)[2]	20.0	4.5	16.8	3.2	19.4	6.1
MUAMA (cm^2)[3]	427.2	57.0	438.2	55.9	422.5	95.7

[1] Body mass index: weight (kg) / height $(m)^2$

[2] The equation of Siri (1956) and Durnin & Womersley (1974) was used.

[3] Mid-upper-arm muscle area: The equation of Frisancho (1990) was used.

b) Female

	Lowland (n = 10)		Hillside (n = 9)		Upland (n = 11)	
	Mean	SD	Mean	SD	Mean	SD
Age (years)	36.5	15.2	37.9	8.2	35.9	11.9
Height (cm)	159.9	5.2	157.0	4.3	156.8	5.6
Weight (kg)	60.0*	9.8	50.3	4.0	54.2	7.4
BMI (kg/m^2) [1]	23.4	3.9	20.4	1.2	22.1	2.9
%fat (%)[2]	33.5	5.5	28.7	3.9	32.5	4.2
MUAMA (cm^2)[3]	346.5	43.4	362.0	45.7	322.8	44.4

[1] Body mass index: weight (kg) / height $(m)^2$

[2] The equation of Siri (1956) and Durnin & Womersley (1974) was used.

[3] Mid-upper-arm muscle area: The equation of Frisancho (1990) was used.

* Significantly higher than in Hillside and Upland ($P < 0.05$)

Food Consumption

Table 3 shows the energy and nutrient intakes of men and women in the 3 zones. Daily energy intake and daily energy intake per fat-free mass did not differ between the 3 groups for either sex. Fat intake and fat energy percent among men in the Lowland group were significantly lower than among men in the other 2 groups ($P < 0.01$), while carbohydrate energy percent was the highest of the 3 groups ($P < 0.01$). Among women, fat intake, carbohydrate intake, and energy percents of fat and carbohydrate did not differ between the 3 groups. Only protein energy percent was lower in the Upland group compared to the Lowland group ($P < 0.05$). Sex differences were not found in the intakes of energy and all nutrients in any of the groups.

The nutrient intakes of the subjects were compared with recommended dietary allowance (RDA: FAO/WHO/UNU, 2004; FAO/WHO, 2002) and safe level (FAO/WHO/UNU, 1985). Percentages of sufficiency of RDA and safe level are described in Figure 2. Table 4 shows RDA of each nutrient. Protein intake among the subjects of this study was said to be mostly adequate, because protein intake of most of the groups reached the safe level except for half of male subjects of the Lowland group. Among men in the Lowland group, energy percent of fat intake of all subjects was also below the proper range, and women in the same group had a high proportion of subjects whose fat intake was below the proper range. The proportions of the subjects who did not meet the RDA for calcium intake was high for both sexes among all groups. While all men met the RDA for iron, a few women from each zone did. Only women of the Lowland group had adequate intake of vitamin C, but among the other groups, the proportions of the subjects who did not meet RDA were high. Most subjects had adequate RDA of vitamin A, except for half of the men in the Lowland group.

Figures 3, 4 and 5 show the proportional contribution of specific food groups to the daily intake of energy, protein, and fat for the 3 groups and for each sex. The proportions of specific food groups contributing to the intake of energy and all macronutrients and micronutrients, except vitamin A and vitamin C for women, were significantly different in all zones ($P < 0.05$). In contrast, sex differences were not found in the Hillside and Upland groups, but the proportional contribution of food groups to the daily intake of protein, fat, and carbohydrate were significantly different between sexes in the Lowland group ($P < 0.05$). Furthermore, subjects in the Lowland group had a high proportion of fish intake, which contributed to protein and fat intakes, and those in the Upland group tended to have a high proportion of roots and tubers contributing to energy and protein intakes.

Table 3. Comparison of daily energy and nutrient intakes of adults living in 3 contrasting ecological zones of Zambia

a) Male

	Lowland (n = 6)		Hillside (n = 10)		Upland (n = 8)	
	Mean	SD	Mean	SD	Mean	SD
Energy (kcal)	2266.7	465.7	3032.0	719.6	2863.4	539.2
Energy (kcal/FFM[1]kg)	48.3	10.7	62.0	11.4	61.6	10.4
Protein (g)	53.7	21.1	75.4	24.5	62.0	13.4
Energy %	9.1	2.1	9.9	1.6	8.6	0.3
Fat (g)	20.3*	6.9	56.6	17.4	46.7	13.6
Energy %	7.8*	1.5	17.1	4.9	14.9	4.2
Carbohydrate (g)	472.1	87.0	557.1	140.3	540.4	99.2
Energy %	83.8**	3.0	73.3	4.4	75.6	7.3
Calcium (mg)	299.9	210.0	432.7	299.1	634.5	405.4
Iron (mg)	16.8	3.4	21.0	5.3	20.2	4.1
Vitamin A (μg)	1850.6	2200.9	4532.7	3330.1	5163.2	2874.2
Vitamin C (mg)	44.5	28.1	26.8	24.6	32.6	21.8

[1] Fat free mass

* Significantly lower than in Hillside and Upland (*P* < 0.01)

** Significantly higher than in Hillside and Upland (*P* < 0.01)

b) Female

	Lowland (n = 10)		Hillside (n = 9)		Upland (n = 11)	
	Mean	SD	Mean	SD	Mean	SD
Energy (kcal)	2681.1	602.6	2595.4	359.6	2476.9	621.4
Energy (kcal/FFM[1]kg)	68.4	16.0	72.6	9.3	68.0	15.3
Protein (g)	73.0	23.8	66.4	10.1	56.9	16.8
Energy %	10.7*	1.8	10.3	1.2	9.1	0.8
Fat (g)	35.6	18.8	43.1	10.1	42.4	20.0
Energy %	11.4	4.3	15.1	3.7	15.0	4.6
Carbohydrate (g)	505.6	74.2	487.6	78.4	464.3	102.5
Energy %	77.0	8.2	75.0	3.7	75.6	6.6
Calcium (mg)	668.0	395.3	369.5	133.0	516.6	416.8
Iron (mg)	26.1**	11.7	20.3	5.7	16.6	3.7
Vitamin A (μg)	6140.4	6881.8	5044.9	2697.3	3819.1	2199.7
Vitamin C (mg)	75.5***	39.2	26.3	17.1	21.1	16.7

[1] Fat free mass

* Significantly higher than in Upland (*P* < 0.05)

** Significantly higher than in Hillside and Upland (*P* < 0.05)

*** Significantly higher than in Hillside and Upland (P < 0.001)

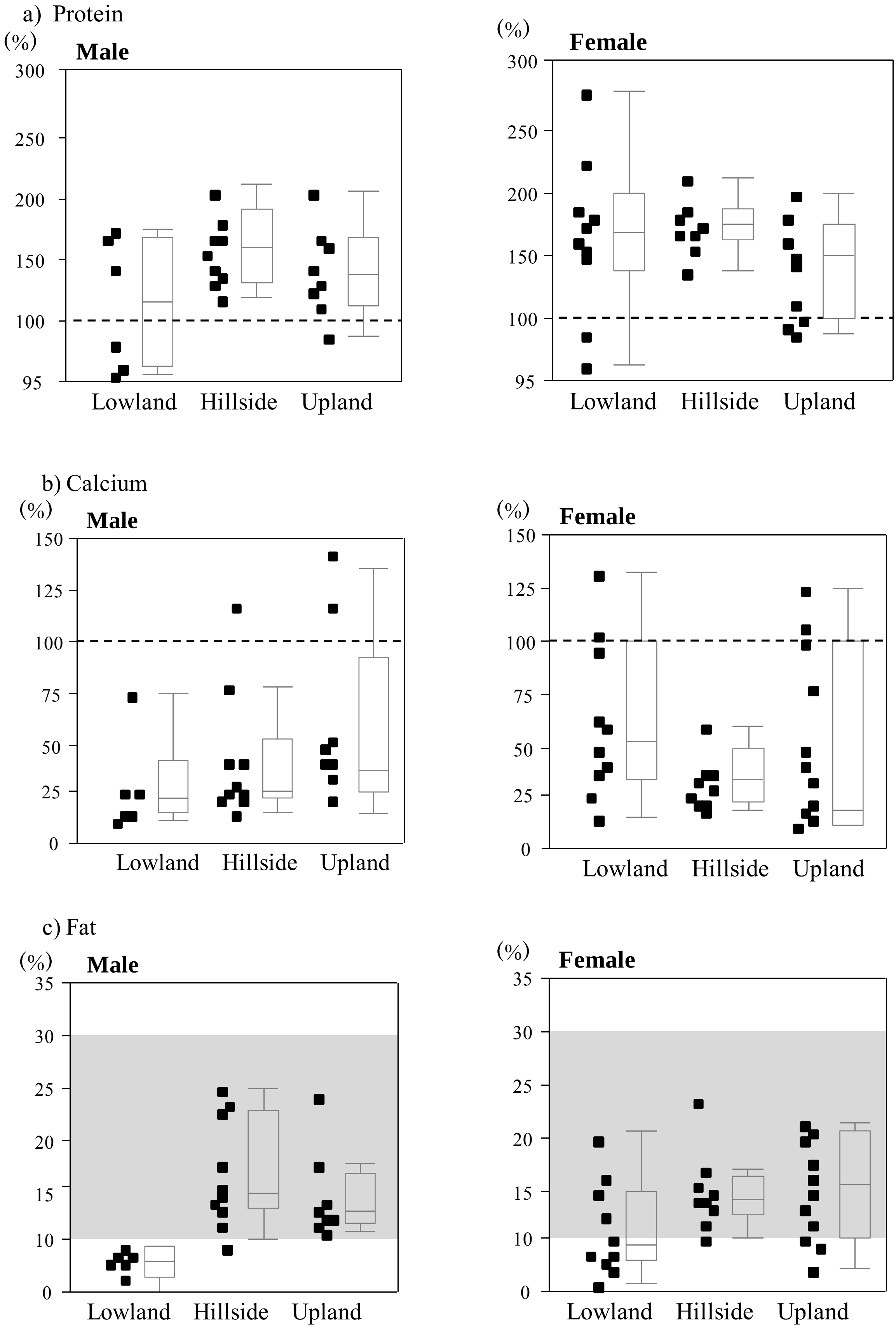

Figure 2. Comparison between nutrient intake and RDA value

Table 4. FAO/WHO Recommended Dietary Allowances

	Male		Female	
Age (years)	18—65	>65	18—50[4]	>50[4]
Protein (g/ kg/day)[1]		0.75		
Fat % energy (%)[2]		10~30		
Calcium (mg)[3]	1000	1300	1000	1300
Iron (mg)[3]	11.4	11.4	24.5	9.4
Vitamin A (μg)[3]	600	600	500	500
Vitamin C (mg)[3]	45	45	45	45

[1] Safe level (FAO/WHO/UNU, 1985)

[2] FAO (1994)

[3] FAO/WHO (2002)

[4] 50 years is the age of menopause defined by Morabia eta al.1998.

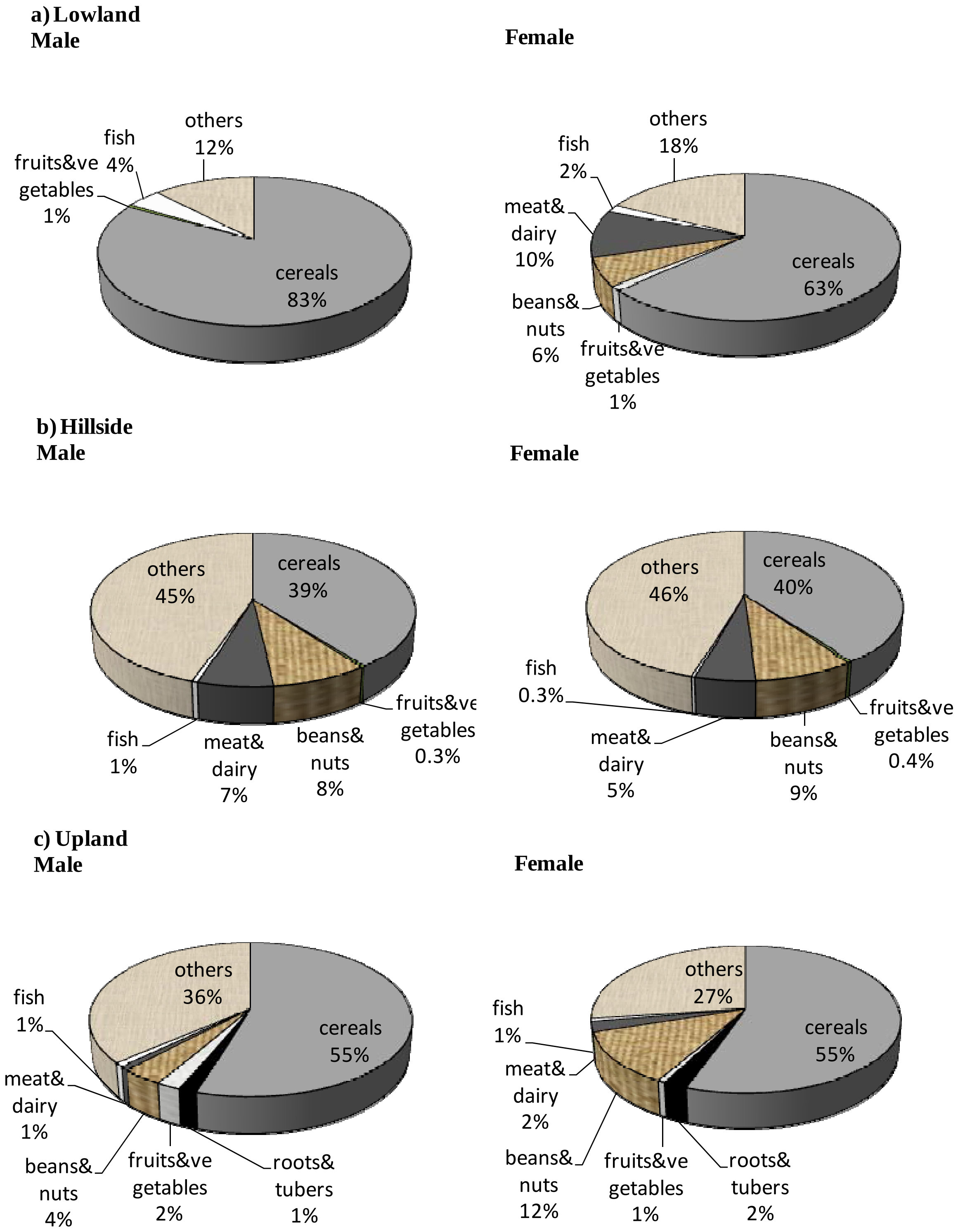

Figure 3. Contribution of specific food groups to daily energy intake

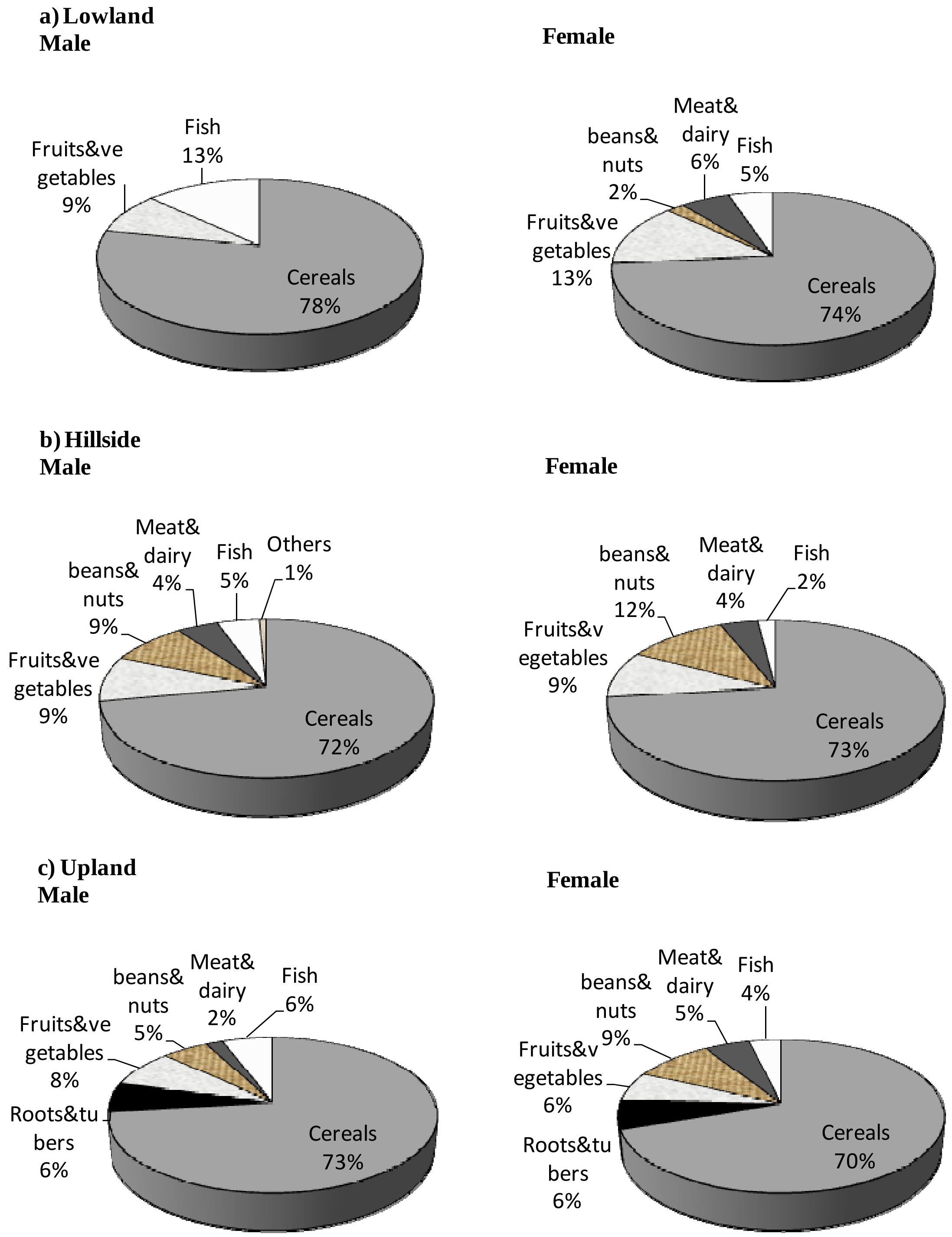

Figure 4. Contribution of specific food groups to daily protein intake

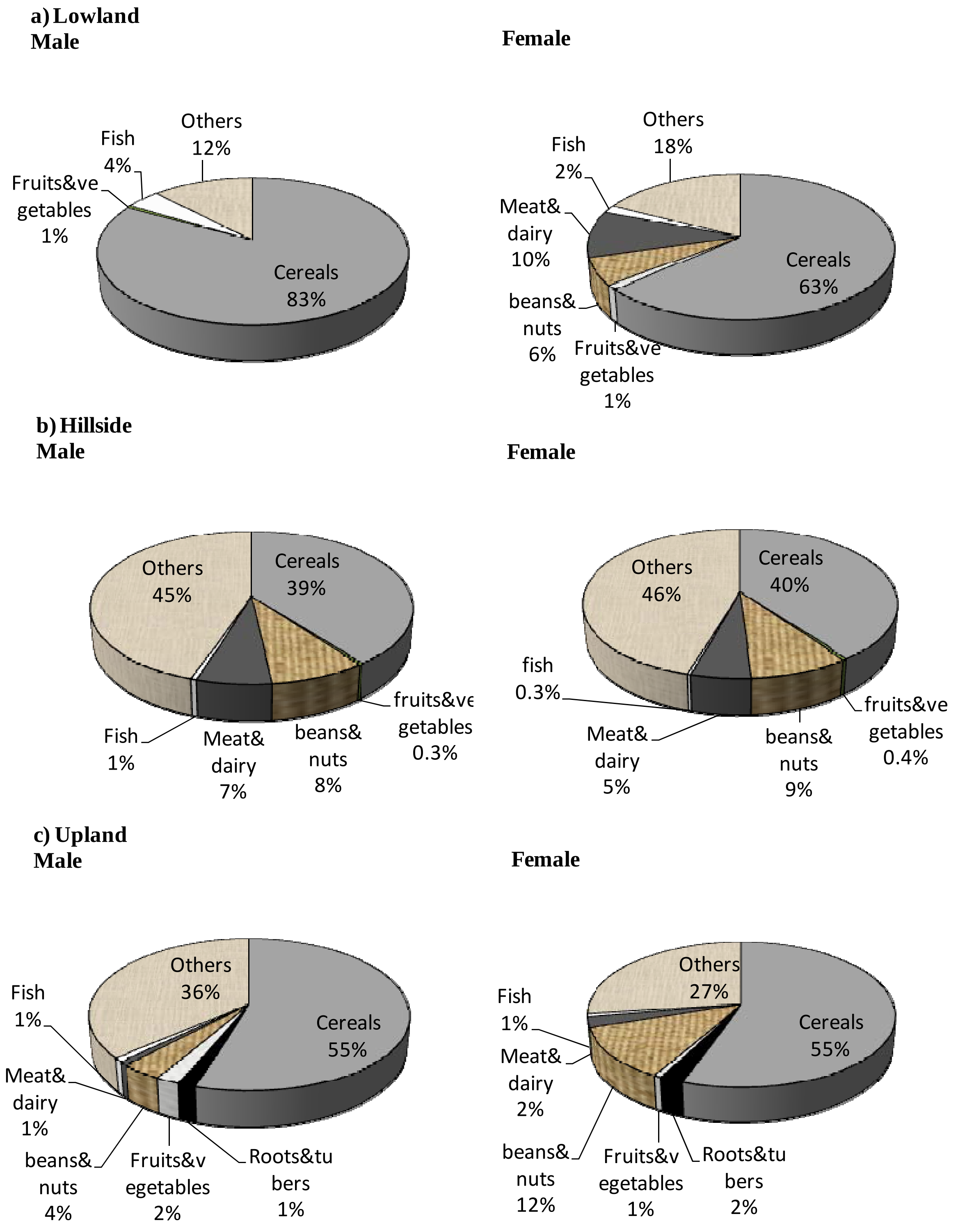

Figure 5. Contribution of specific food groups to daily fat intake

Physical activity and travel patterns

Table 5 shows the estimated BMR and indices of physical activity and travel patterns. TEE, energy balance, and physical activity level (PAL) did not differ significantly between the 3 groups for either sex. Energy balance was within ±1MJ (239 kcal) for men in the Hillside group, and for men and women in the Upland group. Mean PAL was classified as "active" (FAO/WHO/UNU, 2004) for all groups and both sexes. Although there was no significant difference in daily steps or daily total travel path between the 3 groups for either sex, the traveled radius was significantly larger for both men and women in the Hillside group ($P < 0.05$ and $P < 0.01$, respectively). Among the women in the Lowland group, PAL, traveled radius, and daily steps were the lowest of the 3 zones, although not significantly so.

TEE values of men were significantly higher than those of women in the Hillside and Upland groups ($P < 0.001$). In the Lowland and the Hillside group, traveled radius were higher among men ($P < 0.05$ and P < 0.01, respectively), but there was no sex difference among the Upland subjects.

Table 5. Basal metabolic rate and indices of physical activity and travel patterns of adults living in 3 contrasting ecological zones of Zambia

a) Male

	Lowland (n = 7)		Hillside (n = 10)		Upland (n = 9)	
	Mean	SD	Mean	SD	Mean	SD
Weight (kg)	61.1	2.4	50.3	4.0	57.8	2.2
BMR (kcal/day)[1]	1479.0	225.1	1552.7	122.3	1513.5	148.0
TEE (kcal/day)[2]	2535.4	471.9	2790.3	302.5	2728.6	279.4
Balance (kcal/day)[3]	-345.2	699.4	241.7	649.4	177.0	534.2
PAL[4]	1.71	0.08	1.79	0.09	1.81	0.13
Steps (steps/day)	12111	3980	15828	4932	17226	7208
Travel path (km/day)	9.5	6.3	20.6	13.0	11.3	5.5
Traveled radius (km)	4.9	3.7	21.8*	15.4	2.6	2.1

[1] Estimated basal metabolic rate (FAO/WHO/UNU 2004)

[2] Total energy expenditure

[3] TEI (energy intake shown in table2) - TEE

[4] Physical activity level; TEE/BMR

* Significantly higher than in Lowland ($P < 0.01$)

b) Female

	Lowland (n = 10)		Hillside (n = 9)		Upland (n = 11)	
	Mean	SD	Mean	SD	Mean	SD
Weight (kg)	60	9.8	50.3	4	54.2	11.9
BMR (kcal/day)[1]	1307.1	128.9	1249.5	36.6	1288.7	62.3
TEE (kcal/day)[2]	2224.2	253.9	2241.6	113.1	2280.3	152.0
Balance (kcal/day)[3]	456.9	494.4	353.8	395.9	196.6	584.0
PAL[4]	1.70	0.11	1.79	0.08	1.77	0.05
Steps (steps/day)	13681	7589	18643	5604	16414	3004
Travel path (km/day)	8.6	5.4	11.6	3.4	9.6	1.7
Traveled radius (km)	1.8	1.8	4.7*	3.3	2.9	1.6

[1] Estimated basal metabolic rate (FAO/WHO/UNU 2004)

[2] Total energy expenditure

[3] TEI (energy intake shown in table2) - TEE

[4] Physical activity level : TEE/BMR

* Significantly higher than in Lowland ($P < 0.05$)

Discussion

Many studies have reported the variation of nutritional status, food consumption, and physical activity during the busy farming season, but nutritional status actually worsened during the less labor-intensive season for farming (Schofield, 1974; Wandel et al, 1992; Wandel and Holmboe-Ottesen, 1992). It is important to know the actual lifestyle during the less labor-intensive season for farming, particularly to identify the cause of the loss of body weight. This study investigated lifestyle such as dietary, physical activity, and travel patterns in contrasting ecological zones during the less labor-intensive season for farming; then, these were compared among the groups and between sexes. The results show that there are different lifestyles between the 3 groups and sexes.

Difference of lifestyle among the 3 groups

Although there was no difference in energy balance, the proportional contribution of specific food groups to the daily intake of energy and macronutrients were different between the 3 zones. The high fish consumption, and therefore, the high intake of protein between both sexes in the Lowland group were expected because the lowland is adjacent to Lake Kariba. Most subjects in all zones satisfied the safe level of protein, and there was no difference in protein intakes among both sexes between the 3 groups; however, the contribution of fish to the daily intake of protein in the

Lowland group was the highest of the 3 groups. This indicated that people who live in the zones where less fish was consumed could have adequate intake of protein from other food group (i.e. beans & nuts). On the other hand, there was a high proportion of consumption of roots and tubers for intakes of energy and protein among both men and women in the Upland group (Figures 3, 4). This was attributed to the intake of sweet potato only in the Upland group, where sweet potato eaten for breakfast in almost all cases; either porridge or wheat was eaten for breakfast in the Lowland and Hillside. The quantity of protein that was consumed in a meal during the survey was higher in wheat than in sweet potato (data not shown). This could be the factors responsible for cause the low value of protein energy percent among women in the Upland group. Furthermore, wheat is not grown among the sample population, but provided by a non-governmental organization (NGO) group. People may consume more protein from wheat that was provided by the NGO group than from sweet potato, which were grown by them.

Among the Hillside group, distinctive dietary patterns did not appear, but characteristic patterns of physical activity were found. Although there was no significant difference in daily steps or daily total travel path between the 3 groups for either sex, the traveled radius was significantly larger for both men and women in the Hillside group ($P < 0.01$ and $P < 0.05$, respectively). However, 5 male subjects in this group attended a major Christian meeting in Batoka, a town about 35 km away from their village, where many Tongan Christians met during the survey period. This may have expanded their traveled area compared to other subjects who did not attend the meeting. If we measured the mean traveled radius of the 5 male subjects excluding the day they attended the meeting, the mean value and SD is 8.2 ± 8.9. It doesn't show significant difference between the 3 zones, but the mean traveled radius among men in the Hillside group was still the largest of all groups. On the other hand, the subjects, especially women, in the Hillside group had not only the largest traveled radius but also the highest PAL, total daily steps, and daily total traveled path. This might be related to the geographical situation of the Hillside, which is located on the side of a mountain.

The lifestyle such as dietary, physical activity, and travel patterns of adult villagers differed in every zone while the energy balance and the nutritional status were not different. This showed that each group had a different strategy to maintain the proper energy balance and the nutritional status.

Difference of lifestyle between sexes

Many adult men in the Lowland group work in the "kapenta" (Tanganyika sardine) industry and stay overnight near the lake in the less labor-intensive season when there is less agricultural work at home. This might account for the clearer sex difference in diet observed in the Lowland group because couples had meals separately.

Moreover, some male subjects in the Lowland group were absent for a long time during our survey because of their second job, so their diets were assessed by recall interview. Therefore, underestimation of food intake might occur only among the men in the Lowland group. The fact that many male subjects in the Lowland group did not fill safe level in protein, RDA of fat, and vitamin A supported the possibility of their underestimation of food intake. Furthermore, women in the Lowland group had the lowest values of PAL, traveled radius, and total daily steps. The data suggest that women in the Lowland group are likely to be more sedentary than women in the other 2 zones. Compared to women in the other 2 zones, who generally work (e.g. selling fruits and vegetables at the market, farming) in the less labor-intensive season, most women in the Lowland group did not have a specific job, except domestic work. Furthermore, women in the Lowland group who used a hand pump could have fewer loads to carry when they drew water compared to women in the Hillside and Upland groups who drew from a stream.

Among the Upland subjects, there was no gender difference in daily steps, daily total travel path, or traveled radius. In fact, most of the sample households in this group farm even after the harvest of maize, many couples usually work together in their field. This working together of spouses differs from the situation in the other 2 zones, suggesting that both men and women in the Upland group have similar patterns of both amount of physical activity expended and travel patterns.

The more different dietary, physical activity, and travel patterns were between sexes, the more different the body composition between sexes tend to appear. A previous study that investigated the nutritional status of adults in the same areas showed that sex difference of BMI was the largest in the Lowland group and the smallest in the Upland group (Yamauchi and Kon, 2010). The results of this study, where the largest differences of dietary patterns and energy balance were in the Lowland group and there was little difference of physical activity patterns in the Upland group, could support the result of the previous study.

Validity and limitation of this study

Although we used weighed-food method for a single day in this study, the multiple day approach is generally recommended, which has been used in many previous studies even for African population (e.g. Gewa et al, 2008; Kigutha et al, 1997; Mitchikpe et al, 2008). However, dietary patterns in most rural communities tend to be monotonous and hardly vary from day to day or meal to meal (Beaton et al, 1979; Hautvast et al, 1999), this could be applied to our sample populations. Moreover, we explained to the subjects that they should prepare their usual food and they actually did so. Thus, we could assess the usual dietary patterns as regards to kind of foods.

On the other hand, the assessment for quantity of food might not be accurate. Women and children in the sample population usually surround 1 pot or plate, but I used side plates to weigh individual share of meals during the survey and it was not usual way to eat foods for them. We could get more accurate data if we weighed the food as the subjects usually ate without side plates, and carried out multiple day record keeping.

Since there were reported differences of nutritional status among the 3 groups (Yamauchi and Kon, 2010), we expected to find not only the difference of lifestyle but also a difference of nutritional status among the 3 groups. This, however, did not appear, perhaps because of the small sample size, which was as small as 56. However, previous studies which performed weighed-food method among African populations had as few subjects as this study (cf. Mitchikpe et al., 2008). The weighed dietary record was the most appropriate method for accurate dietary data in non-literate rural communities (Kigutha, 1997), and the data obtained in this study had more accuracy compared to the data from recall or questionnaire methods even with 1-day method.

In contrast, underestimations were likely in the assessment of energy expenditure using an accelerometer sensor. In a previous report with parameters similar to our study, August–September corresponded to the season when adults lost body weight. Although it was expected that the energy balance of most subjects would be negative values, most subjects actually had positive values. Not only the underestimation of energy expenditure but the overestimation of food consumption could promote bias to a positive value.

Lastly, because this study was a cross-sectional study that was conducted only during the less labor-intensive season for farming, both the data of this study and the data for food consumption, physical activity, and travel patterns for other seasons could show how lifestyle connected to nutritional status. Further investigation with the same type of survey during the busy farming season is needed to reveal the differences of lifestyle between the less labor-intensive season for farming and the busy farming season to show that the food consumption and physical activities during the less labor-intensive season for farming are more important factors for maintaining healthy conditions.

Conclusions

Variations of food consumption, physical activity, and travel patterns between 3 neighboring ecological zones in the Southern province of Zambia, and between the sexes were investigated. Food consumption, physical activity, and travel patterns of adult villagers differed in every zone while the energy balance and the nutritional status were not different. Therefore, it was suggested that each contrasting ecological zone had a strategy to maintain the proper energy balance and the health condition of the people. It was also shown that each group has different characteristic of lifestyle between the sexes. Further investigations during the busy farming season are needed to reveal that lifestyle during the less labor-intensive season for farming is more important for maintaining healthy conditions.

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