

# Low dietary diversity and micronutrient adequacy among lactating women in a peri-urban area of Nepal

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Submitted 23 June 2014: Final revision received 21 January 2015: Accepted 23 January 2015: First published online 31 March 2015

## Abstract

**Objective:** The main objectives were to assess the adequacy of the micronutrient intakes of lactating women in a peri-urban area in Nepal and to describe the relationships between micronutrient intake adequacy, dietary diversity and sociodemographic variables.

**Design:** A cross-sectional survey was performed during 2008–2009. We used 24 h dietary recall to assess dietary intake on three non-consecutive days and calculated the probability of adequacy (PA) of the usual intake of eleven micronutrients and the overall mean probability of adequacy (MPA). A mean dietary diversity score (MDDS) was calculated of eight food groups averaged over 3 d. Multiple linear regression was used to identify the determinants of the MPA.

**Setting:** Bhaktapur municipality, Nepal.

**Subjects:** Lactating women (*n* 500), 17–44 years old, randomly selected.

**Results:** The mean usual energy intake was 8464 (SD 1305) kJ/d (2023 (SD 312) kcal/d), while the percentage of energy from protein, fat and carbohydrates was 11 %, 13 % and 76 %, respectively. The mean usual micronutrient intakes were below the estimated average requirements for all micronutrients, with the exception of vitamin C and Zn. The MPA across eleven micronutrients was 0.19 (SD 0.16). The diet was found to be monotonous (MDDS was 3.9 (SD 1.0)) and rice contributed to about 60 % of the energy intake. The multiple regression analyses showed that MPA was positively associated with energy intake, dietary diversity, women's educational level and socio-economic status, and was higher in the winter.

**Conclusions:** The low micronutrient intakes are probably explained by low dietary diversity and a low intake of micronutrient-rich foods.

## Keywords

Dietary diversity  
Micronutrient adequacy  
Lactating women  
Peri-urban Nepal

Breast-feeding is one of the most important factors that can influence child health in low- and middle-income countries<sup>(1,2)</sup>. During lactation, women have increased requirements for energy and micronutrients<sup>(3,4)</sup>. An inadequate maternal intake of certain nutrients during this period may have consequences for both the mother's health and nutritional status, as well as those of the breast-fed infant<sup>(5–7)</sup>. The breast-milk levels of some micronutrients vary with the mother's own stores and dietary intake; the nutrients most affected by low maternal intake and stores are thiamin, riboflavin, vitamins A, D, B<sub>6</sub>, B<sub>12</sub>, Se and iodine<sup>(5–8)</sup>.

Women in low- and middle-income countries are at high risk of inadequate intake of several micronutrients<sup>(9,10)</sup>. Despite the particular importance of good maternal nutrition

during the lactation period, there is a dearth of information on lactating mothers' micronutrient intakes<sup>(11)</sup> and a great need for more studies documenting the adequacy of nutrient intakes during this critical period.

Urbanization is a major trend in most low- and middle-income countries and is likely influencing dietary intake in many ways. However, few studies have assessed the adequacy of micronutrient intake among urban populations<sup>(12,13)</sup>. The objectives of the present paper were to assess the adequacy level of the micronutrient intakes of lactating women in a peri-urban area (Bhaktapur) in Nepal and to describe relationships between micronutrient intake adequacy, dietary diversity and socio-demographic variables.

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## Methods

### **Study design and population**

A cross-sectional survey was carried out among 500 randomly selected healthy lactating women (17–44 years old) from the Bhaktapur municipality, Nepal. Bhaktapur is an urban area located 15 km east of the capital of Kathmandu and was chosen because of the socio-economic diversity of this population, which offers a unique opportunity to explore dietary variation. It has a total population of approximately 75 000, made up predominantly of the Newari ethnic group, with mostly farmers, semi-skilled or unskilled labourers and daily wage earners.

The sample size of our study was chosen based on the assumption that the prevalence of dietary deficiency of key micronutrients including Zn, Fe and vitamin B<sub>12</sub> would be 25%, with a desired absolute precision of 4%. Assuming incomplete sampling from approximately 10% of these women we calculated a final desired sample size of 500 women. For several years nutrition-related research has been undertaken in this area and demographic information has been collected and used to estimate population density in the different geographic areas (*toles*). In the first stage of sampling we used a probability-proportional-to-size method to select sixty-six of 160 *toles*. In the second stage we obtained census lists of all women who had given birth over the last 12 months in the sixty-six *toles* and who were still breast-feeding, and selected randomly from these lists. We had to approach 582 women in order to enrol 500 women in the study. A total of 500 lactating women (both exclusively breast-feeding and partially breast-feeding) were enrolled in the study and completed the first 24 h dietary recall. Due to loss to follow-up, the sample sizes for the second and third 24 h recalls were 487 and 477, respectively. Eleven women were excluded due to incomplete 24 h recalls; therefore the final sample size consisted of 466 lactating women who had completed three 24 h recalls.

The women participating in the study came to the hospital to receive physical examinations, dietary interviews and blood draws. The first woman was enrolled in January of 2008 and the last in February of 2009. The inclusion criteria were that the women were lactating, had no self-reported ongoing infections and were able to provide household information. Women with anaemia (Hb < 12.3 g/dl) were offered free treatment with Fe supplements according to the national guidelines. All women provided written informed consent before the start of the study, which was approved by the ethical review board of the Institute of Medicine at Tribhuvan University in Nepal.

### **Dietary data collection**

Each woman participated in three 24 h recalls<sup>(14)</sup> which were conducted by Nepali- and Newari-speaking fieldworkers. The fieldworkers were trained in interview techniques, the use of electronic scales, estimation of the

volume of different foods, collection of recipes and the use of food codes by a dietitian over a 2-month period prior to the study. This included a pilot study in which each fieldworker practised the 24 h recall interview on five women. To minimize interviewer bias and to help ensure that the recalls reflected typical dietary consumption, recalls for each woman were obtained on three different days (including weekends) with 2–11 d separating the recall period, by three different fieldworkers. Data collection took place over one year in order to reflect seasonal variations in their diets.

At the hospital, a technique of multiple-pass 24 h recalls was used<sup>(14)</sup>. During each 24 h recall the women were asked to name all foods and drinks consumed during the preceding day, including anything consumed outside the home, as well as the time of consumption. They were also asked to describe the ingredients and cooking methods used for any recipe prepared during the recall period. The amounts of the foods and dishes were estimated using an electronic scale (Philips scales, England) with a precision of 1 g and a maximum capacity of 5 kg, which was calibrated daily. Cooked rice was used to estimate the volume of rice, vegetable curry (*tarkari*) and pickles. Water was used to estimate the volume of lentil soup (*dal*), and fresh vegetables were used to measure the size and quantity of the vegetables in the recipes. Utensils commonly used in the households were purchased and used at the hospital for estimating amounts. Clay models were used to estimate the portion sizes of meat and fish, wooden models were used for bread, and pictures were used to estimate the size of the fruits that were consumed. Finally, the women were asked to recall snacks (foods consumed between meals) during the previous 24 h from a list of snacks prepared for the study. Additionally, recipes for items prepared at home were collected and used. For items commonly consumed or purchased outside the house, including tea, spices (*masala*), lentil soup, bread, vegetable curry and pickles, a set of standard recipes were developed and used based on the pilot study in which twelve recipes from each dish were collected and the averages of ingredients were taken. Information on the consumption of fortified foods was not collected. Most of the fortified foods available in the area were designed for infants and pre-school children, and were not commonly consumed by adults.

### **Dietary data analysis**

Because there is no standard food composition table available for Nepal, a food composition table was compiled for the present study which drew upon nutrient values for foods from WorldFood 2<sup>(15)</sup>, the *Nutritive Value of Indian Foods*<sup>(16)</sup> and, where necessary, from the Thai food composition table<sup>(17)</sup> or the US food composition table<sup>(18)</sup>. The three 24 h dietary recalls and the compiled food composition table were entered into nutrient analysis software designed for the study where it was possible to enter both dietary intake and personal recipes. The 24 h

recalls were then converted into daily nutrient intakes. Retinol equivalents (RE) were calculated as the sum of retinol and  $\beta$ -carotene, using the following conversions: 1  $\mu\text{g}$  retinol = 1  $\mu\text{g}$  RE and 1  $\mu\text{g}$   $\beta$ -carotene = 0.167  $\mu\text{g}$  RE<sup>(19)</sup>.

The prevalence of adequate nutrient intakes was assessed with the three 24 h recalls and the Institute of Medicine's probability approach<sup>(20)</sup>, using the statistical software package STATA 12.0. The nutrient intakes, which were skewed, were transformed using a Box–Cox transformation. Then, using the transformed intake variables, we calculated within- and between-person variances and the best linear unbiased predictor of the usual intake for each nutrient for each woman. The best linear unbiased predictors were also used to calculate the probability of adequacy for each nutrient<sup>(21)</sup>. The usual macronutrient intake distributions were calculated by the Multiple Source Method<sup>(22,23)</sup>, which is characterized by a two-part shrinkage technique applied to the residuals of two regression models, one for the positive daily intake data and one for the event of consumption.

The adequacy of the micronutrient intake was assessed using the WHO/FAO (2004) Estimated Average Requirements (EAR) for vitamins A, C, B<sub>6</sub> and B<sub>12</sub>, folate, thiamin, riboflavin, niacin and Fe<sup>(4)</sup>. For Ca, the Institute of Medicine EAR from 2011 was used<sup>(24)</sup>, and for Zn we used the International Zinc Nutrition Consultative Group EAR for a mixed or refined diet, assuming 34% bioavailability<sup>(25)</sup>. The estimation of the dietary Fe availability in this population was calculated according to Murphy *et al.*<sup>(26)</sup> and Bhargava *et al.*<sup>(27)</sup>, and gave average bioavailabilities of 4.5% and 1.8%, respectively. The WHO recommends the use of a calculation of 5 or 10% Fe absorption in developing countries, depending on the diet<sup>(19)</sup>. Therefore, we used the 5% bioavailability assumption for the evaluation of Fe intake in the present study.

The SD of the requirements was calculated using the CV of the requirements and the EAR; the CV was 12.5% for Zn<sup>(25)</sup>, 20% for vitamin A, 15% for niacin, 10% for vitamins C, B<sub>6</sub> and B<sub>12</sub>, thiamin, riboflavin, niacin, folate<sup>(28)</sup> and Ca<sup>(24)</sup>, and 30% for Fe<sup>(20)</sup>. The probability of adequacy (PA) was calculated for each nutrient, ranging from 0 to 1, and an overall mean PA (MPA) was calculated by averaging the PA values across the eleven nutrients for each individual. When the PA for a nutrient is averaged across individuals, it is equivalent to the population prevalence of adequacy expressed as a percentage<sup>(20)</sup>.

The use of Black's adaptation of the Goldberg approach to identify under- and over-reporters was investigated for the sample<sup>(29)</sup>. In this approach, the estimated energy intake is divided by the BMR and the resulting BMR factor is compared with lower and upper cut-offs of the physical activity levels acceptable for the population. The usual estimated energy intake was calculated by the Multiple Source Method described above and the BMR was estimated by the FAO/WHO equation, while adding extra energy expenditures due to lactation (2092 kJ/d

(500 kcal/d) for women with children below 6 months and 1674 kJ/d (400 kcal/d) for women with children above 6 months of age<sup>(3)</sup>. When comparing the resulting BMR factor with the lower and upper 95% CI for the 3 d dietary records and sedentary lifestyle according to Black<sup>(29)</sup>, forty-six women were classified as under-reporters. We decided not to exclude these women since we could not rule out the possibility that they were actually low consumers with a negative energy balance and because there was no material difference to the findings in a sensitivity analysis excluding them.

Dietary diversity scores (DDS) were calculated using eight food groups, similar to the FAO methodology, with the exception of organ meat being included with meat and fish<sup>(30)</sup>. The eight food groups included: (i) starchy staples; (ii) dark green leafy vegetables; (iii) other vitamin A-rich fruits and vegetables; (iv) other fruits and vegetables; (v) meat and fish; (vi) eggs; (vii) legumes, nuts and seeds; and (viii) milk and milk products. We used a restrictive minimum amount consumed of 15 g/d in order for the women to be counted as having consumed a food group<sup>(31)</sup>. The DDS was calculated by summing the number of food groups consumed on each day and averaging it over the 3 d<sup>(32)</sup>. The mean DDS for the 3 d is denoted as MDDS.

#### **Anthropometric measurements**

The measurements of the weights of the women were conducted by using a UNICEF weighing scale (Salter; SECA, Germany) and the heights were measured with a locally made board in the clinic that was calibrated weekly. The maternal BMI was calculated as weight/height<sup>2</sup> (kg/m<sup>2</sup>); BMI < 18.5 kg/m<sup>2</sup> was considered to be underweight, while 18.5 ≤ BMI < 25.0 kg/m<sup>2</sup> was considered a normal weight and BMI ≥ 25.0 kg/m<sup>2</sup> was overweight.

#### **Statistical analysis**

The data were analysed using the statistical software packages SPSS version 17 and STATA version 12. Continuous data were presented as mean and standard deviation, and, for data that were not normally distributed, as the median. Pearson correlation coefficients were calculated to describe the relationships between energy intake, MPA and MDDS.

Prior to including variables in regression models, all continuous variables were log or square-root transformed to obtain normality. Variables were categorized as follows: educational level was used as a continuous variable; parity was categorized into 1 and ≥ 2 children; women's occupation was categorized into 'no paid employment' and 'paid employment'; husbands' occupation was categorized into 'no paid employment/agriculture/carpet corder', 'daily wage earner' and 'self-employed/services/working abroad'. Seasons were defined as pre-monsoon (March–May), monsoon (June–August), post-monsoon (September–November) and winter (December–February). All covariates showing a

linear association ( $P < 0.20$ ) in the crude regression model with MPA as outcome were included in a preliminary multiple regression model. Excluded variables were reintroduced, and those that were still significantly associated in this model ( $P < 0.20$ ) were retained in the final model<sup>(33)</sup>.

We identified predictors for MPA in multiple linear regression models and present three separate models. A theory-based approach was used for selection of candidate variables for inclusion in the models. Model 1 included intake variables that would directly influence MPA, such as dietary diversity and energy intake which reflects amounts consumed. Model 2 included external factors which were hypothesized to influence dietary intake and thus micronutrient intake adequacy. An initial crude model 2 included infant's age and sex, women's age, parity and BMI, women's and husband's educational levels and occupation, socio-economic status indicated by house ownership (rent or own) and seasonality. A third model included predictors from both model 1 and 2. The intakes of the food groups were included in a separate regression model together with energy intake to examine which food groups were main determinants for the MPA. We analysed the residuals of these models to examine their fit. An adjustment for clustering within the *toles* was done using the 'SVY' group of commands for complex survey data in STATA.

## Results

The mean age of the lactating women was 25.7 (SD 4.1) years (Table 1), the mean age of the breast-feeding children was 6.8 (SD 3.0) months and the mean duration of exclusive breast-feeding was 0.9 (SD 1.4) months. Forty-one per cent of the women had one child, 42% had two children and 18% had three or more children. The mean BMI was 22.4 (SD 3.1) kg/m<sup>2</sup>; and 78.7% had a normal BMI (between 18.5 and 25.0 kg/m<sup>2</sup>), 16.6% were classified as overweight and 4.7% as underweight. Additionally, 29.7% had completed school up to the 10th grade and 18.5% of the women were illiterate. Most of the women (65.6%) had no paid work, while 15.5% were daily wage earners and 7.1% were self-employed. Thirty-seven per cent of the women's families rented a house, while 63% were home owners.

### Macro- and micronutrient intakes

The mean energy intake was 8464 (SD 1305) kJ/d (2023 (SD 312) kcal/d; Table 2). On average, the percentage of energy derived from protein was 11%, from fat was 13% and from carbohydrates was 76%. The mean or median usual micronutrient intakes were below the EAR for all micronutrients except vitamin C and Zn (Table 3). The women's mean or median prevalence of adequacy was  $\leq 1\%$  for folate, riboflavin and vitamin B<sub>12</sub>; between 2% and 25% for thiamin, vitamin A and Ca; between 25% and 50% for niacin, vitamin B<sub>6</sub>, vitamin C and Fe; and 66% for

**Table 1** Descriptive personal and household characteristics\* of lactating women ( $n$  466) aged 17–44 years, Bhaktapur municipality, Nepal, January 2008–February 2009

Characteristic	Value
Age (years)	
Mean	25.7
SD	4.1
Age of breast-fed child (months)	
Mean	6.8
SD	3.0
Parity	
Mean	1.8
SD	0.9
One child (%)	40.9
Two children (%)	41.5
Three or more children (%)	17.6
BMI (kg/m <sup>2</sup> )	
Mean	22.4
SD	3.1
<18.5 (%)	4.7
18.5–25.0 (%)	78.7
$\geq 25.0$ (%)	16.6
Mother's schooling (%)	
No schooling	18.5
Primary school (1st–3rd grade)	34.5
Secondary school (4th–10th grade)	29.7
Above secondary†	17.3
Father's schooling (%)	
No schooling	5.8
Primary school (1st–3rd grade)	30.4
Secondary school (4th–10th grade)	42.2
Above secondary†	21.6
Mother's employment (%)	
No paid employment	65.6
Agriculture	7.7
Carpet worker	2.4
Daily wage earner	15.5
Self-employed	7.1
Services	1.7
Father's employment (%)	
No paid employment	1.0
Agriculture	6.0
Carpet worker	1.5
Daily wage earner	50.1
Self-employed	24.9
Services	11.4
Working abroad	4.9
Lived in a rented house (%)	37.0

\*Values are means and standard deviations or percentages.

†Intermediate, School Leaving Certificate (SLC) or bachelor's degree.

zinc; and the MPA across eleven micronutrients was 0.19 (SD 0.16). Including the twenty-three women with incomplete number of recalls (twelve women with one recall and eleven women with two recalls) resulted in only minor changes in PA while MPA was unchanged.

### Dietary pattern and food intake

The typical dietary pattern consisted of three main meals: breakfast (with morning tea at about 07.00 hours and rice with side dishes at about 08.00 hours), lunch and dinner (Table 4). The daily diet was characterized by the consumption of large amounts of rice with side dishes (typically vegetable curry, lentil soup and pickles). The vegetable curry was usually made of potatoes, green leaves, some vegetables and *masala* spices (garlic, chilli, ginger, cumin,

**Table 2** Usual energy and macronutrient intakes\*, and recommended intakes, of lactating women (n 466) aged 17–44 years, Bhaktapur municipality, Nepal, January 2008–February 2009

	Energy		Protein	Fat	Carbohydrates
	kJ/d	kcal/d	g/d		
Mean	8464	2023	53	30	383
SD	1305	312	10	9	59
Median	8360	1998	52	29	380
	%				
Mean % of energy intake	–	–	11	13	76
WHO/FAO recommendations	10 305	2463†	10–15‡	15–30‡	55–75‡

\*Usual energy and macronutrient intakes according to the Multiple Source Method<sup>(22,23)</sup>.  
 †Estimated energy requirement for an ‘average’ woman aged 18–29 years weighing 50 kg and with light physical activity (8205 kJ/d (1961 kcal/d)), plus extra energy for lactation (2100 kJ/d (502 kcal/d))<sup>(3)</sup>.  
 ‡WHO/FAO recommendations for macronutrient intakes are expressed as percentages of energy<sup>(3)</sup>.

**Table 3** Micronutrient requirements, usual micronutrient intakes\*, prevalence of adequacy and MPA in lactating women (n 466) aged 17–44 years, Bhaktapur municipality, Nepal, January 2008–February 2009

	Requirements†		Usual intake according to BLUP‡			Prevalence of adequacy (%)	
	EAR	SD	Mean	SD	Median	Mean	SD
Thiamin (mg/d)	1.2	0.12	0.78	0.23	0.78	5	0.8
Riboflavin (mg/d)	1.3	0.13	0.62	0.18	0.59	1	0.3
Niacin (mg/d)	13.0	1.95	11.40	3.34	11.10	31	1.6
Vitamin B <sub>6</sub> (mg/d)	1.7	0.17	1.45	0.37	1.44	26.7	1.6
Folate (µg/d)	450	45	163.8	70.0	147.9	0.3	0.2
Vitamin B <sub>12</sub> (µg/d)	2.4	0.24	0.49	0.53	0.31	1	0.3
Vitamin C (mg/d)	55.0	5.5	60.0	27.6	46.3	36	2.0
Vitamin A (RE/d)	450	90	188.9	220.2	104.4	11	1.3
Ca (mg/d)	800	100	430.0	203.8	390.8	6.6	1.0
Fe (mg/d)§	23.4	7.02	17.4	8.6	15.2	28	1.4
Zn (mg/d)	7.0	0.88	7.80	1.60	7.63	66	1.6
MPA across 11 micronutrients						0.19	0.16
Median						0.15	

MPA, mean probability of adequacy; EAR, Estimated Average Requirement; RE, retinol equivalent.  
 \*The mean is the overall mean of each individual’s usual intake based on 3 d recall.  
 †The EAR are for lactating women; the EAR for vitamins A, C, B<sub>6</sub> and B<sub>12</sub>, folate, thiamin, riboflavin, niacin and Fe were from WHO/FAO 2004<sup>(4)</sup>. For Ca, the Institute of Medicine EAR from 2011 was used<sup>(24)</sup>. For Zn, the International Zinc Nutrition Consultative Group EAR for a mixed or refined diet was used assuming 44 % bioavailability<sup>(25)</sup>. The SD of requirements was calculated using the CV of requirements and the EAR; the CV were 12.5 % for Zn<sup>(25)</sup>, 20 % for vitamin A, 15 % for niacin, 10 % for vitamins C, B<sub>6</sub>, B<sub>12</sub>, thiamin, riboflavin, folate<sup>(28)</sup> and Ca<sup>(24)</sup>, and 30 % for Fe<sup>(20)</sup>.  
 ‡Best linear unbiased predictor<sup>(21)</sup>.  
 §Assuming 5 % bioavailability.  
 ||The mean probability of adequacy is the average of the probability of adequacy of the eleven micronutrients.

**Table 4** Percentage who consumed main types of dishes for breakfast, lunch and dinner, and the dishes’ contribution to energy intake (based on three 24 h recalls), among lactating women (n 466) aged 17–44 years, Bhaktapur municipality, Nepal, January 2008–February 2009

Dish	Breakfast*		Lunch†		Dinner‡		Contribution to energy intake (%)
	%	n	%	n	%	n	
Rice	99.6	464	32.2	15	99.6	464	49
Vegetable curry ( <i>tarkari</i> )	97.0	452	65.0	303	95.9	447	11
Pickles	57.5	268	20.4	95	47.9	223	1
Lentil soup ( <i>dal</i> )	50.0	233	8.8	41	50.6	236	3
Roti (unleavened bread)	6.7	31	34.1	159	0.6	3	3
Beaten rice (flattened rice)	6.0	28	63.9	298	10.9	51	12
Tea	86.9	405	62.4	291	5.2	24	5

\*Breakfast includes foods and drinks consumed from 06.00 hours in the morning to 12.00 hours.  
 †Lunch includes foods and drinks consumed from 12.00 to 18.00 hours.  
 ‡Dinner includes foods and drinks consumed from 18.00 to 0.00 hours.



salt, oil and turmeric). These dishes were commonly consumed for both breakfast and dinner. For lunch, vegetable curry, beaten rice (flattened rice), unleavened bread (*roti*) and tea were most commonly consumed. Snacking was relatively frequent (by 76%), and the most common snacks were buns, doughnuts, *samosa* and biscuits. Alcohol, mainly rice beer, was consumed by 23% of the women and the mean intake was 125 g/d. When looking at the use of ready-made foods (purchased food, made outside the household), ready-made vegetable curry and ready-made pickles were the most commonly consumed (by 30% and 25%, respectively).

The main contributors to the women's total energy intake were white cooked rice, beaten rice and vegetable curry, contributing 49%, 12% and 11% of the energy, respectively (Table 4). Both *roti* and *dal* contributed 3% of the total energy intake.

The MDDS ranged from 1.3 to 6.7, with a mean of 3.9 (SD 1.0). Starchy staples were consumed by all the women, whereas dark green leafy vegetables, legumes, nuts and seeds, and other fruits and vegetables were consumed by 79–83%. The meat and fish food group was consumed by 62%, with meat representing 98% of the intake from this group. Milk (separately or with tea) was consumed by 68%, including curd, which was consumed by 13%. The meat and milk were mainly from buffalo, with mean daily intakes of 47 g and 94 g, respectively; while the eggs (consumed by 25%) were mainly from chickens (mean daily intake was 23 g).

#### **Determinants of mean probability of adequacy**

The MPA was highly correlated with the energy intake ( $r=0.71$ ,  $P<0.001$ ) and it was also significantly correlated with the MDDS ( $r=0.30$ ,  $P<0.001$ ). In the multivariate analysis controlling for energy, the association between the MPA and MDDS was attenuated but still significant (Table 5).

In the second multivariate model, the MPA among the women was positively associated with the women's age, educational level, ownership of the house they were living in and the winter season. When combining all covariates in a joint regression model, the women's education, house ownership, and winter or pre-monsoon season had a significant positive association with MPA, along with energy intake and MDDS. The final model explained 56% of the variance in the MPA (Table 5).

Multivariate regression analyses were conducted to determine which of the eight food groups were predictive of the MPA (data not shown). In a regression model unadjusted for energy intake, the intake of all food groups was significantly positively associated with the MPA. When adjusting for energy intake, the intake of staples was significantly negatively associated with the MPA, whereas the intakes of dark green leafy vegetables, vitamin A-rich and other fruits and vegetables, as well as meat and fish,

remained significant positive predictors of the MPA. Adjusting for sociodemographic factors did not change these findings.

#### **Discussion**

The adequacy of the overall micronutrient intake among lactating women was low (19%) in this peri-urban area of Nepal, and the adequacy was particularly low for some micronutrients (riboflavin, vitamin B<sub>12</sub>, folate, thiamin, Ca and vitamin A). The high micronutrient requirements for lactating women combined with a low intake of micronutrient-rich foods are the main explanatory factors for the low MPA.

The lactating women in the present study had an energy intake below their estimated requirements; protein intake was within the acceptable range of 10–15% of the energy contribution, whereas the fat intake was in the lower range and the carbohydrate intake was correspondingly high, compared with the WHO/FAO recommendations<sup>(3)</sup>. These findings are in line with other studies evaluating the diet of Nepalese women<sup>(34–36)</sup>. Rice contributed about 61% of the women's total energy intake: rice with vegetable curry and, to a certain extent, lentil soup was widely consumed by the women, as described in other studies from Nepal<sup>(35,36)</sup>.

The low adequacy of the intake of folate, vitamin B<sub>12</sub> and riboflavin in the present study coincides with the findings of studies among women of reproductive age from Burkina Faso<sup>(12)</sup>, Mali<sup>(31)</sup> and Bangladesh<sup>(32)</sup>. Additionally, vitamin B<sub>12</sub> deficiency is quite common and is mainly explained by a diet low in animal products<sup>(37)</sup>. Two previous studies of pregnant women in Nepal documented that vitamin B<sub>12</sub> deficiency (serum level < 150 pmol/l) was common; 49% in Kathmandu<sup>(38)</sup> and 28% in the Sarlahi District<sup>(9)</sup>. In our study, the main sources of vitamin B<sub>12</sub> were meat, dairy products and eggs, which were consumed in small amounts by 62%, 68% and 25% of the women, respectively.

Two prior studies of pregnant Nepali women each found a low prevalence of folate deficiency: 7% < 4.5 nmol/l<sup>(38)</sup> and 11% < 6.7 nmol/l<sup>(9)</sup>. A study on folate status in Nepali infants found that folate deficiency was non-existent<sup>(39)</sup>. It is therefore surprising that the probability of adequate folate intake was close to zero for the women in our study. This low folate intake could be due to an underestimation of the intake of folate-containing foods. Although folate-containing green leafy vegetables and lentils were consumed by more than 80% of the women in the study and were the main sources of folate (41% and 15%, respectively), the reported quantities consumed were also small (65 g/d and 35 g/d, respectively). The low folate intake might also be due to an underestimation of the folate content of the foods in the food composition table, which is a recognized problem<sup>(40)</sup>.

Only one-third of the women in our study had a diet which covered the EAR for Fe. In another analysis of the same population, we found a low prevalence of anaemia and Fe deficiency, which may be explained by the widespread use

**Table 5** Summary of multiple linear regression models for variables predicting MPA\* of micronutrient intakes among lactating women (*n* 466) aged 17–44 years, Bhaktapur municipality, Nepal, January 2008–February 2009

Variables	Model 1				Model 2†				Model 3			
	<i>B</i>	95 % CI	$\beta$	<i>P</i>	<i>B</i>	95 % CI	$\beta$	<i>P</i>	<i>B</i>	95 % CI	$\beta$	<i>P</i>
Energy and dietary diversity												
Energy‡,§	8.30	7.50, 9.10	0.68	<0.001					7.95	7.15, 8.75	0.65	<0.001
MDDSI	0.77	0.31, 1.23	0.11	0.001					0.63	0.17, 1.10	0.09	0.008
Women's characteristics												
Age‡					1.37	0.30, 2.44	0.12	0.012	0.59	-0.17, 1.36	0.05	0.13
BMI‡					0.59	-0.68, 1.85	0.04	0.36	-0.62	-1.54, 0.29	-0.04	0.18
Years of schooling‡,¶					1.03	0.61, 1.46	0.26	<0.001	0.46	0.15, 0.73	0.12	0.003
Household characteristics												
Housing												
Rents					Referent							
Owns					0.45	0.13, 0.78	0.12	0.007	0.35	0.11, 0.58	0.09	0.004
Husband's years of schooling‡,¶					0.35	-0.18, 0.89	0.07	0.19	0.08	-0.31, 0.47	0.01	0.70
Season												
Monsoon					Referent				Referent			
Post-monsoon					-0.33	-1.01, 0.35	-0.04	0.34	-0.26	-0.74, 0.23	-0.03	0.30
Winter					1.00	0.42, 1.56	0.15	0.001	0.78	0.37, 1.18	0.12	<0.001
Pre-monsoon					0.34	-0.60, 1.03	0.04	0.34	0.65	0.15, 1.15	0.08	0.01
Adjusted <i>R</i> <sup>2</sup>			0.51				0.14				0.56	
Observations			465				459				458	

MPA, mean probability of adequacy.

\*Square-root transformed.

†Linear regression model with MPA as the dependent variable and the independent variables that remained significant at the *P*<0.20 level after initial testing. Variables which were tested but not found significant were infant's age and sex, parity, women's occupation and husband's occupation.

‡Natural-log transformed.

§Usual energy intake according to the Multiple Source Method<sup>(22,23)</sup>.

||Mean dietary diversity score.

¶Treated as continuous variable from 1 (no schooling) to 6 (higher education).

of Fe/folic acid supplements during pregnancy<sup>(41)</sup>. Because the lifespan of erythrocytes is >90 d, the intake of prenatal Fe supplements is likely to have had a positive effect on Hb concentration for the first few postnatal months. It is unlikely that these women cover their needs for Fe through their diet, based on the low intakes of Fe-rich foods. Our estimates of Zn intake are in line with other studies of Nepalese women of reproductive age<sup>(36,42)</sup>. A study from Bhaktapur showed that more than three-quarters of the women were Zn deficient as defined by low plasma Zn concentrations, despite a relatively high intake of Zn (mean intake of 8.6 mg/d)<sup>(42)</sup>. One explanation could be that the typically high intake of phytic acid in the Nepali diet inhibits absorption of Zn or that the food composition table might not be reflecting the actual content of Zn. Another explanation could be that Zn intake is a poor marker of Zn status. In fact, Chandyo *et al.* demonstrated that phytic acid, but not Zn intake, predicted plasma Zn concentration and that phytic acid was negatively associated with plasma Zn levels<sup>(42)</sup>.

The women's diet was characterized by a low DDS and similar to those previously reported in women in Bangladesh using the same definition of dietary diversity<sup>(32)</sup>. The correlation between dietary diversity and overall micronutrient intake adequacy was also similar to what was found among the Bangladeshi women<sup>(32)</sup>, but not as strong as found among women from five resource-poor settings in five developing countries<sup>(31)</sup>. The MPA was mainly determined by the energy intake and dietary diversity.

One-third of the women had bought ready-made foods, but these foods covered only 1 % of their energy intake. Another urban food practice was snacking (consumption between meals), which was practised by 76 % of the women and contributed to 4 % of the energy intake. The most frequent snacks were ready-made *samosa*, doughnuts and different types of local baked goods (*sel*, *bom*, *puri*, *momo* and *nimki*), most of which had a high content of fat and sugar<sup>(43)</sup>.

The lactating women in the present study represented a relatively well-off Nepali peri-urban population; nevertheless, their level of micronutrient inadequacy was high and this was partly due to a low dietary diversity. Strategies to increase dietary diversity, and in particular the intakes of vitamin-A rich fruits and vegetables, eggs, dairy products, meat and fish, are warranted in this population. Other strategies such as micronutrient supplementation and fortification should also be considered<sup>(44)</sup>. The intake of processed foods was relatively low at the time of the study; however, changes and 'Westernization' of the diet, and the potential consequences, should be monitored<sup>(13,45)</sup>.

Our study had a number of strengths. For example, we had a representative sample of lactating women, with a relatively large sample compared with most other dietary studies. We knew the population size of each cluster (*tole*) from previous studies in this area and the probability of selecting a cluster was proportional to its population size. A list of eligible women from all clusters was generated

and the women were randomly selected from the list. Based on this procedure all the women had approximately similar probability of being selected. We therefore believe that that our sampling approach yielded a representative sample of the population living in and around Bhaktapur municipality. There is, of course, a risk that some of our population estimates were inaccurate or that the population had changed since our last census. However, we do not think that this would have had any meaningful impact on our estimates, which is also supported by the fact that the design effect (i.e. the effect of clustering) was negligible. We had three interactive 24 h recalls with personal recipes adapted to local foods which are more likely to represent typical diet than a single recall. Similarly the fact that interviews were done throughout the year enabled us to capture seasonal variations in food. However, a weakness of our study was the reliance on external food composition tables, which may not reflect the true nutrient composition of local Nepali foods.

## Conclusions

The lactating women in this peri-urban area had an inadequate intake of several micronutrients, which may compromise their own health as well as that of their infants. The main causes of the low MPA were low dietary diversity and low quantities of micronutrient-rich foods. Investigations into the consequences of maternal and infant micronutrient status are warranted, as is the implementation of policies and programmes to improve the nutritional situation of women and children in Nepal.

## Acknowledgements

*Financial support:* This work was supported by a grant from the Norwegian Council of Universities' Committee for Development Research and Education (project number NUFUSM-2007/10177); the Research Council of Norway (project number 172226); and a grant from the GCRieber Funds and Feed the Future Food Security Innovation Lab: Collaborative Research on Nutrition, which is funded by the US Agency for International Development and the National Institutes of Health (training grant number T32 #DK 007703). The funders had no role in the design, analysis or writing of this article. *Conflict of interest:* None. *Authorship:* T.A.S., R.C., S.H., W.W.F. and P.S.S. formulated the research questions and designed the study; R.C. and S.H. conducted the data collection; S.H. and L.E.T. analysed the data; S.H., L.E.T. and A.L.T-L. wrote the paper; S.H., L.E.T. and T.A.S. had primary responsibility for the final content; all authors read and approved the final manuscript. *Ethics of human subject participation:* Ethical clearance was given by the Institute of Medicine at Tribhuvan University in Nepal.



## References

1. Black RE, Victora CG, Walker SP *et al.* (2013) Maternal and child undernutrition and overweight in low-income and middle-income countries. *Lancet* **382**, 427–451.
2. Bhutta ZA, Das JK, Rizvi A *et al.* (2013) Evidence-based interventions for improvement of maternal and child nutrition: what can be done and at what cost? *Lancet* **382**, 452–477.
3. United Nations University/World Health Organization/Food and Agriculture Organization of the United Nations (2001) *Human Energy Requirements. Report of a Joint FAO/WHO/UNU Expert Consultation*. Rome: FAO.
4. World Health Organization/Food and Agriculture Organization of the United Nations (2004) *Vitamin and Mineral Requirements in Human Nutrition*, 2nd ed. Geneva: WHO.
5. Allen LH (2012) B vitamins in breast milk: relative importance of maternal status and intake, and effects on infant status and function. *Adv Nutr* **3**, 362–369.
6. Azizi F & Smyth P (2009) Breastfeeding and maternal and infant iodine nutrition. *Clin Endocrinol (Oxf)* **70**, 803–809.
7. Dawodu A & Tsang RC (2012) Maternal vitamin D status: effect on milk vitamin D content and vitamin D status of breastfeeding infants. *Adv Nutr* **3**, 353–361.
8. Butte N, Lopez-Alarcon MG & Garza C (2002) *Nutrient Adequacy of Exclusive Breastfeeding for the Term Infant During the First Six Months of Life*. Geneva: WHO.
9. Jiang T, Christian P, Khatry SK *et al.* (2005) Micronutrient deficiencies in early pregnancy are common, concurrent, and vary by season among rural Nepali pregnant women. *J Nutr* **135**, 1106–1112.
10. Allen LH (2005) Multiple micronutrients in pregnancy and lactation: an overview. *Am J Clin Nutr* **81**, issue 5, 1206S–1212S.
11. Torheim LE, Ferguson EL, Penrose K *et al.* (2010) Women in resource-poor settings are at risk of inadequate intakes of multiple micronutrients. *J Nutr* **140**, issue 11, 2051S–2058S.
12. Becquey E & Martin-Prevel Y (2010) Micronutrient adequacy of women's diet in urban Burkina Faso is low. *J Nutr* **140**, issue 11, 2079S–2085S.
13. Smith C (2013) Determinants of western food adoption among Hindu Nepalese women living in the Kathmandu valley. *Am J Hum Biol* **25**, 205–214.
14. Gibson RS & Ferguson EL (2008) *An Interactive 24-Hour Recall for Assessing the Adequacy of Iron and Zinc Intakes in Developing Countries HarvestPlus Technical Monograph no. 8*. Washington, DC and Cali: IFPRI and CIAT.
15. Food and Agriculture Organization of the United Nations (2010) Food Composition: Overview of the WorldFood Dietary Assessment System. [http://typo3.fao.org/fileadmin/templates/food\\_composition/documents/World\\_food\\_dietary\\_assessment\\_system/Overview\\_of\\_the\\_WorldFood\\_Dietary\\_Assessment\\_System.pdf](http://typo3.fao.org/fileadmin/templates/food_composition/documents/World_food_dietary_assessment_system/Overview_of_the_WorldFood_Dietary_Assessment_System.pdf) (accessed December 2014).
16. Gopalan C, Rama Sastri B & Balasubramanian S (1989) *Nutritive Value of Indian Foods*. Hyderabad: National Institute of Nutrition, Indian Council of Medical Research.
17. Institute of Nutrition, Mahidol University (2002) *Food Composition Database for INMUCAL Program*. Salaya, Thailand: Institute of Nutrition, Mahidol University.
18. US Department of Agriculture, Agricultural Research Service (2012) Search the USDA National Nutrient Database for Standard Reference. <http://ndb.nal.usda.gov/> (accessed December 2014).
19. World Health Organization & Food and Agriculture Organization of the United Nations (2002) *Human Vitamin and Mineral Requirements. Report of a Joint WHO/FAO Expert Consultation, Bangkok, Thailand*. Rome: FAO.
20. Institute of Medicine (2000) *Dietary Reference Intakes: Applications in Dietary Assessment*. Washington, DC: National Academies Press.
21. Joseph ML & Carriquiry A (2010) A measurement error approach to assess the association between dietary diversity, nutrient intake, and mean probability of adequacy. *J Nutr* **140**, issue 11, 2094S–2101S.
22. Haubrock J, Nothlings U, Volatier JL *et al.* (2011) Estimating usual food intake distributions by using the multiple source method in the EPIC-Potsdam Calibration Study. *J Nutr* **141**, 914–920.
23. Harttig U, Haubrock J, Knuppel S *et al.* (2011) The MSM program: web-based statistics package for estimating usual dietary intake using the Multiple Source Method. *Eur J Clin Nutr* **65**, Suppl. 1, S87–S91.
24. Institute of Medicine (2011) *Dietary Reference Intakes for Calcium and Vitamin D*. Washington, DC: National Academies Press.
25. International Zinc Nutrition Consultative Group, Brown KH, Rivera JA *et al.* (2004) International Zinc Nutrition Consultative Group (IZiNCG) technical document #1. Assessment of the risk of zinc deficiency in populations and options for its control. *Food Nutr Bull* **25**, 1 Suppl. 2, S99–S203.
26. Murphy SP, Beaton GH & Calloway DH (1992) Estimated mineral intakes of toddlers: predicted prevalence of inadequacy in village populations in Egypt, Kenya, and Mexico. *Am J Clin Nutr* **56**, 565–572.
27. Bhargava A, Bouis HE & Scrimshaw NS (2001) Dietary intakes and socioeconomic factors are associated with the hemoglobin concentration of Bangladeshi women. *J Nutr* **131**, 758–764.
28. Institute of Medicine (2006) *Dietary Reference Intakes: The Essential Guide to Nutrient Requirements*. Washington, DC: National Academies Press.
29. Black AE (2000) Critical evaluation of energy intake using the Goldberg cut-off for energy intake: basal metabolic rate. A practical guide to its calculation, use and limitations. *Int J Obes Relat Metab Disord* **24**, 1119–1130.
30. Kennedy G, Ballard T & Dop M-C (2010) *Guidelines for Measuring Household and Individual Dietary Diversity*. Rome: FAO.
31. Arimond M, Wiesmann D, Becquey E *et al.* (2010) Simple food group diversity indicators predict micronutrient adequacy of women's diets in five diverse, resource-poor settings. *J Nutr* **140**, issue 11, 2059S–2069S.
32. Arsenaault JE, Yakes EA, Islam MM *et al.* (2013) Very low adequacy of micronutrient intakes by young children and women in rural Bangladesh is primarily explained by low food intake and limited diversity. *J Nutr* **143**, 197–203.
33. Hosmer DW & Lemeshow S (2000) *Applied Logistic Regression*, 2nd ed. New York: John Wiley & Sons Inc.
34. Reynolds RD, Moser PB, Acharya S *et al.* (1988) Nutritional and medical status of lactating women and their infants in the Kathmandu valley of Nepal. *Am J Clin Nutr* **47**, 722–728.
35. Ohno Y, Hirai K, Sato N *et al.* (1997) Food consumption patterns and nutrient intake among Nepalese living in the southern rural Terai region. *Asia Pacific J Clin Nutr* **6**, 251–255.
36. Parajuli RP, Umezaki M & Watanabe C (2012) Diet among people in the Terai region of Nepal, an area of micronutrient deficiency. *J Biosoc Sci* **44**, 401–415.
37. Allen LH (2009) How common is vitamin B-12 deficiency? *Am J Clin Nutr* **89**, issue 2, 693S–696S.
38. Bondevik GT, Schneede J, Refsum H *et al.* (2001) Homocysteine and methylmalonic acid levels in pregnant Nepali women. Should cobalamin supplementation be considered? *Eur J Clin Nutr* **55**, 856–864.
39. Ulak M, Chandyo RK, Adhikari RK *et al.* (2014) Cobalamin and folate status in 6 to 35 months old children presenting with acute diarrhea in Bhaktapur, Nepal. *PLoS One* **9**, e90079.

40. Institute of Medicine (1998) *Dietary Reference Intakes for Thiamin, Riboflavin, Niacin, Vitamin B<sub>6</sub>, Folate, Vitamin B<sub>12</sub>, Pantothenic Acid, Biotin, and Choline*. Washington DC: National Academy Press.
41. Henjum S, Manger M, Skeie E *et al.* (2014) Iron deficiency is uncommon among lactating women in urban Nepal, despite a high risk of inadequate dietary iron intake. *Br J Nutr* **112**, 132–141.
42. Chandyo RK, Strand TA, Mathisen M *et al.* (2009) Zinc deficiency is common among healthy women of reproductive age in Bhaktapur, Nepal. *J Nutr* **139**, 594–597.
43. Steyn NP, Mchiza Z, Hill J *et al.* (2014) Nutritional contribution of street foods to the diet of people in developing countries: a systematic review. *Public Health Nutr* **17**, 1363–1374.
44. Mason JB, Saldanha LS, Ramakrishnan U *et al.* (2012) Opportunities for improving maternal nutrition and birth outcomes: synthesis of country experiences. *Food Nutr Bull* **33**, 2 Suppl., S104–S137.
45. Turin TC, Shahana N, Wangchuk LZ *et al.* (2013) Burden of cardio- and cerebro-vascular diseases and the conventional risk factors in South Asian population. *Glob Heart* **8**, 121–130.