Public Health Nutrition: 8(7), 837–843 DOI: 10.1079/PHN2005746

Maternal micronutrient status and decreased growth of Zambian infants born during and after the maize price increases resulting from the southern African drought of 2001–2002

R Gitau[1], M Makasa[2], L Kasonka[3], M Sinkala[2], C Chintu[3], A Tomkins[1] and S Filteau[1,4,]*
[1]Institute of Child Health, London, UK: [2]Lusaka District Health Management Team, Lusaka, Zambia: [3]University Teaching Hospital, Lusaka, Zambia: [4]Nutrition and Public Health Interventions Research Unit, London School of Hygiene and Tropical Medicine, Keppel Street, London WC1E 7HT, UK

Submitted 24 January 2005: Accepted 11 April 2005

Abstract

Objective: To investigate the effects on maternal micronutrient status and infant growth of the increased maize prices that resulted from the southern African drought of 2001–2002.
Design: Longitudinal cohort study.
Setting: A maternal and child health clinic in Lusaka, Zambia.
Subjects: Maternal and infant health and nutrition data and maternal plasma were being collected for a study of breast-feeding and postpartum health. Samples and data were analysed according to whether they were collected before (June to December 2001), during (January 2002 to April 2003) or after (May 2003 to January 2004) the period of increased maize price. Season and maternal HIV status were controlled for in analyses.
Results: Maize price increases were associated with decreased maternal plasma vitamin A during pregnancy ($P = 0.028$) and vitamin E postpartum ($P = 0.042$), with the lowest values among samples collected after May 2003 (vitamin A: 0.96 μmol l^{-1}, 95% confidence interval (CI) 0.84–1.09, $n = 38$; vitamin E: 30.8 μmol mmol^{-1} triglycerides, 95% CI 27.2–34.8, $n = 64$) compared with before January 2002 (vitamin A: 1.03 μmol l^{-1}, 95% CI 0.93–1.12, $n = 104$; vitamin E: 38.9 μmol mmol^{-1} triglycerides, 95% CI 34.5–43.8, $n = 47$). There were no significant effects of sampling date on maternal weight, haemoglobin or acute-phase proteins and only marginal effects on infant weight. Infant length at 6 and 16 weeks of age decreased progressively throughout the study (*P*-values for time of data collection were 0.51 at birth, 0.051 at 6 weeks and 0.026 at 16 weeks).
Conclusions: The results show modest effects of the maize price increases on maternal micronutrient status. The most serious consequence of the price increases is likely to be the increased stunting among infants whose mothers experienced high maize prices while pregnant. During periods of food shortages it might be advisable to provide micronutrient supplements even to those who are less food-insecure.

Keywords
Famine
Micronutrients
Pregnancy
Stunting

Natural or man-made disasters that lead to decreased food availability may result in cases of severe malnutrition. However, these cases are only the tip of the iceberg and many more people are likely to experience hunger for macronutrients or 'hidden hunger' for micronutrients[1], with consequences for their health. These people are often not a priority in emergencies, so the extent of their problems is frequently not addressed or even documented.

In southern Africa the rains came late and were insufficient for good maize production in late 2001. This resulted in increased prices for maize, the main staple in the region, for the following year, with prices approximately doubling in Lusaka, Zambia from January 2002 until the following May 2003 when the crop fed by the adequate rains beginning in late 2002 was harvested[2]. Many people went hungry but even those of higher incomes able to afford sufficient maize for energy balance may have lacked money for more expensive micronutrient-rich foods such as meat or fruits. Consumption of staples is likely to be relatively inelastic with respect to price[3]. For example, in neighbouring Zimbabwe energy intake is insignificantly affected by food price[4]; and during the Indonesian financial crisis of 1998 when rice prices rose steeply, iron status of women and young children was more seriously affected than was weight[5]. In Zambia the national programme for fortification of sugar with vitamin A has resulted in sugar being an important source of

**Corresponding author:* Email Suzanne.Filteau@lshtm.ac.uk

vitamin A in the national diet[6]. Sugar is a luxury which is likely to be consumed less when more of the family food budget needs to be spent on maize. There appears to have been little research into the sources of vitamin E in Zambian diets, but maize oil is likely to be important.

In a fairly middle-class area of Lusaka, Zambia with a very high HIV prevalence[7], we conducted a study of breast-feeding and postpartum health. Data collection took place from June 2001 until the beginning of January 2004, thus including times before, during and after the period of high maize prices. Throughout the study standardised health questionnaires were used by the same field staff to collect information from pregnant and lactating women and their infants. Blood was collected from women at 34 weeks' gestation and 6 weeks postpartum for analysis of haemoglobin, plasma vitamin A and vitamin E, and plasma acute-phase proteins. At birth, 6 and 16 weeks postpartum, infant weight and length were measured. We used these data to determine whether the maize price increases had any significant effects on the health and nutrition of this fairly protected urban population.

Subjects and methods

The longitudinal cohort study conducted in Chilenje, Lusaka, Zambia was designed to determine factors associated with subclinical mastitis among HIV-infected and uninfected women. The study received ethical approval from the ethics committees of the University of Zambia and the Institute of Child Health/Great Ormond Street Hospital. Details of the main study are published elsewhere[8]. Recruitment at 32–34 weeks' gestation was carried out from June 2001 to July 2003 and follow-up to 16 weeks postpartum ended at the beginning of January 2004. Inclusion criteria for the study were residence within the Chilenje clinic catchment area, known HIV status, and written informed consent. HIV status could be either positive or negative but, since for cost and logistical reasons we aimed to recruit equal numbers of infected and uninfected women, there were more eligible uninfected women than could be recruited; the decision for recruitment was therefore based on the need to recruit similar numbers of infected and uninfected women in parallel.

At recruitment a senior midwife administered a standardised questionnaire investigating personal and socio-economic status and reproductive history. Gestational age was determined from the last menstrual period. Women's weight was measured by the senior midwife using a Soehnle digital balance and height using a Harpenden stadiometer. Venous blood samples (10 ml) were collected in heparinised tubes from non-fasting subjects for measurement of haemoglobin (by Hemocue, Dronfield, UK), plasma vitamin A and E, and the acute-phase proteins, C-reactive protein (CRP) and α_1-acid glycoprotein (AGP).

Most deliveries took place at Chilenje clinic unless the senior midwife or study obstetrician referred them to the University Teaching Hospital (UTH). Since deliveries were facility-based, it was possible to obtain birth weight (UTH and Chilenje) using a digital balance and length (Chilenje only) using a length mat (Starters Baby Measure Mat) immediately after birth for most infants except the 24 who were born at home or in a clinic not involved in the study. There were 11 scheduled postpartum home or clinic follow-up visits for collection of maternal and infant health data up to 16 weeks postpartum. At the 6-week clinic visit maternal blood was collected and at weeks 6 and 16 infant weight and length were measured.

Laboratory analyses

Blood samples were centrifuged and plasma was stored frozen at −80°C until transport to London on dry ice for assay. Plasma retinol (vitamin A) and α-tocopherol (vitamin E) were measured together by high-performance liquid chromatography[9]. The interassay coefficient of variation of a pooled plasma sample was 6% for both retinol and α-tocopherol and there was no overall trend in the values of this quality control sample over the course of the study. α-Tocopherol was expressed as a ratio to plasma triglycerides, measured on a COBAS Fara autoanalyser using a commercial kit (Roche Diagnostics), since α-tocopherol is highly correlated with triglycerides[10] and plasma triglycerides increase during pregnancy[11]. CRP and AGP were measured by enzyme-linked immunosorbent assay and turbidimetry, respectively, as described previously[12]. Interassay coefficients of variation were 10% for AGP and 12% for CRP. In some cases biochemical data were missing because of laboratory error or there was insufficient plasma for all assays.

Statistical analyses

All data were double-entered into EpiInfo 6 (Centers for Disease Control and Prevention, Atlanta, GA, USA), cross-checked, and imported into SPSS 11.0 (SPSS Inc., Chicago, IL, USA) for analysis. Data for α-tocopherol/triglycerides, CRP and AGP were log-normally distributed and were transformed before analysis. The effect of maize price increases on maternal blood constituents was examined by dividing the samples according to the dates they were collected: before price increases, i.e. before January 2002; during high prices, i.e. January 2002–April 2003; and after prices decreased again, i.e. May 2003 to the end of the study. Initial examination of data for vitamins, acute-phase proteins and haemoglobin suggested slight, although not always significant, seasonal effects. Therefore, a factor for season was included in analyses of the effects of maize price increases, where seasons were early dry (June–August), late dry (September–November), early rainy (December–February) and late rainy (March–May), analogous to those found to have significant effects on birth weight in Harare with a similar climate[13]. Maternal HIV status was also found to affect the micronutrient and acute-phase protein levels, so HIV status was included as a covariate.

Infant anthropometry was expressed as standard deviation (Z) scores using the British growth standards[14]. Analyses of Z-scores were run with and without controlling for gestational age at birth; results were very similar, so only values without the gestational age correction are presented. Analyses were first conducted as described above for maternal micronutrients using as independent variables the maize price period during which measurements were made, season and maternal HIV status. Secondly, anthropometric results were analysed by dividing infants into 3-month cohorts according to their date of birth. Birth dates began in June 2001 so that the 3-month intervals were in parallel with the seasons defined above. The four last infants, who were born in early September 2003, were included with the group born June to August 2003. The two types of analysis produced similar results but only the second ones are presented since these permitted easier identification of what period in foetal or infant life coincided with the increased maize prices. For both analyses, maternal HIV status was included as a covariate since it affected infant anthropometry.

Results

Of the initial 429 women, 186 HIV-infected and 186 uninfected women continued in the study to at least 6 weeks postpartum and 177 of each group until 16 weeks. Withdrawals were influenced by maternal HIV status since 36 uninfected women and 15 HIV-infected were lost to follow-up or moved out of the area. In addition, since the main study focused on breast-feeding, three HIV-infected women, but no uninfected women, were dropped from the study when they stopping breast-feeding before 16 weeks. Infants of five uninfected and 16 infected women died before 16 weeks.

Table 1 shows socio-economic and other descriptive data of the women at recruitment when pregnant. The population was middle-income by Zambian standards. Most lived in medium-density housing, rated themselves as not poor, ate at least 3 meals a day, had electricity in the home and half had refrigerators. Most women were housewives whose main source of income was their husbands. Over a quarter of the women had some tertiary education. There were no socio-economic differences detected between HIV-infected and uninfected women. Height and weight indicated an adequately nourished population (although body mass index was not calculated since women were 34 weeks' pregnant). Mild anaemia, 90–110 $g\,l^{-1}$, was common but few women had severe anaemia.

Table 1 Characteristics of the 429 women at recruitment at 32–34 weeks' gestation

HIV-infected, *n* (%)	211 (49)
Age (years), mean (SD)	24.2 (5.2)
Weight (kg), mean (SD)	63.8 (9.0)
Height (cm), mean (SD)	160 (6)
Haemoglobin ($g\,l^{-1}$), mean (SD)	107 (16)
Haemoglobin 90–110 $g\,l^{-1}$, *n* (%)	173 (40)
Haemoglobin $<90\,g\,l^{-1}$, *n* (%)	55 (13)
Primiparous, *n* (%)	170 (40)
Education, *n* (%)	
$\leq$ 6 years	69 (16)
7–11 years	244 (57)
$\geq$ 12 years	116 (27)
Married, *n* (%)	309 (72)
Household finances, *n* (%)*	
Not poor	246 (57)
Poor	177 (41)
Very poor	6 (1.4)
Housing density, *n* (%)*	
Low	51 (12)
Medium	279 (65)
High	99 (23)
Electricity in home, *n* (%)	350 (82)
Refrigerator in home, *n* (%)	211 (49)
3 or more meals daily, *n* (%)	372 (87)

SD – standard deviation.
*Locally understood, self-reported, terms; lower density housing implies greater wealth.

Figure 1 shows plasma retinol and α-tocopherol/triglyceride data in pregnancy and postpartum according to the time of blood collection. Mean levels of both vitamins were within normal ranges[15] except for some slightly low values of retinol during pregnancy. Plasma levels of both vitamins were higher postpartum than during pregnancy. For retinol this was likely due primarily to pregnancy haemodilution[16], whereas an additional factor for α-tocopherol/triglycerides is the increase in plasma lipids during pregnancy[11]. Seasonal variations are apparent, particularly for retinol during pregnancy and α-tocopherol/triglycerides postpartum.

The analyses of the effect of maize price increases on plasma vitamins are shown in Table 2. For both vitamins A and E and both time points, HIV infection was associated with significantly lower plasma vitamin levels. There were significant effects of maize price increase on vitamin A during pregnancy and vitamin E postpartum, with – in both cases – the lowest levels found in samples collected after the maize price had decreased again. Low plasma retinol can result from infection[17] as well as from poor vitamin A status, and in the present study plasma retinol was negatively correlated with CRP during pregnancy ($r = -0.19$, $P < 0.001$, $n = 396$) and both CRP ($r = -0.26$, $P < 0.001$, $n = 320$) and AGP ($r = -0.21$, $P < 0.001$, $n = 322$) postpartum. Acute-phase proteins did not correlate significantly with plasma vitamin E. Therefore, analyses for retinol were rerun with AGP and CRP as additional covariates; results (not shown) were virtually unchanged.

There were no significant associations of season or maize price increases with maternal weight at recruitment

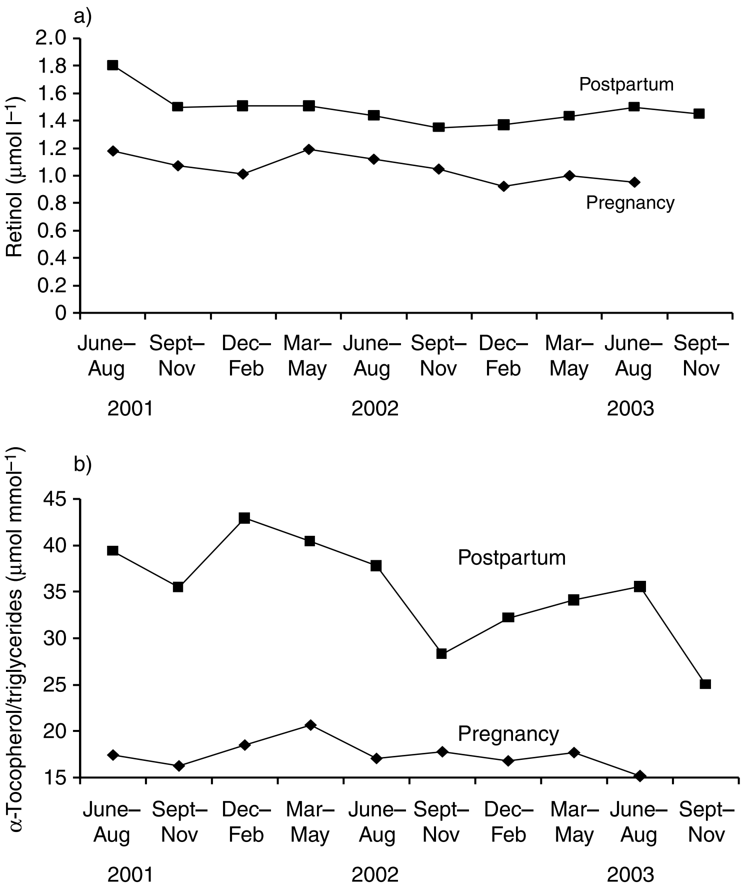

Fig. 1 Effect of sampling date on plasma retinol (a) and α-tocopherol/triglycerides (b) during pregnancy and postpartum. Values are arithmetic (vitamin A, a) or geometric (vitamin E, b) means; each point represents 24–61 samples. Error mean squares from analyses of variance were: pregnancy retinol, 0.137; postpartum retinol, 0.243; pregnancy log α-tocopherol/triglycerides, 0.154; postpartum log α-tocopherol/triglycerides, 0.161. Maize prices were high from January 2002 to April 2003

or with haemoglobin, CRP and AGP at recruitment or 6 weeks postpartum (data not shown).

Infant weight and length showed some seasonal variation, with a trend toward lower values for infants born from September to November (Fig. 2). The effects of cohort on weight at 6 weeks ($P = 0.038$) and 16 weeks ($P = 0.078$) appeared to result largely from this seasonal effect. However, for length at 6 and 16 weeks, there was, superimposed on this seasonal variation, a progressive decrease throughout the study. Maternal HIV status was a

Table 2 Effect of maize price increases on plasma levels of vitamin A and E in Zambian women

			ANOVA *P*-value		
	Time*	Adjusted mean (95% CI), *n*	Maize price	Season	HIV
Vitamin A, pregnancy (μmol l^{-1})	Before	1.03 (0.93–1.12), 104	0.028	0.004	0.045
	During	1.07 (1.02–1.12), 256			
	After	0.96 (0.84–1.09), 38			
Vitamin A, postpartum (μmol l^{-1})	Before	1.58 (1.43–1.73), 48	0.12	0.48	0.006
	During	1.42 (1.35–1.49), 210			
	After	1.50 (1.35–1.65), 65			
Vitamin E, pregnancy (μmol $mmol^{-1}$ triglycerides)	Before	17.2 (15.4–19.1), 98	0.81	0.065	0.047
	During	17.8 (16.9–18.8), 256			
	After	17.6 (15.5–20.0), 38			
Vitamin E, postpartum (μmol $mmol^{-1}$ triglycerides)	Before	38.9 (34.5–43.8), 47	0.042	0.026	<0.001
	During	34.9 (33.0–37.0), 209			
	After	30.8 (27.2–34.8), 64			

CI – confidence interval; ANOVA – analysis of variance.

*Time in relation to maize price increases; before = before January 2002, during = January 2002 to April 2003, after = May 2003 to end of study.

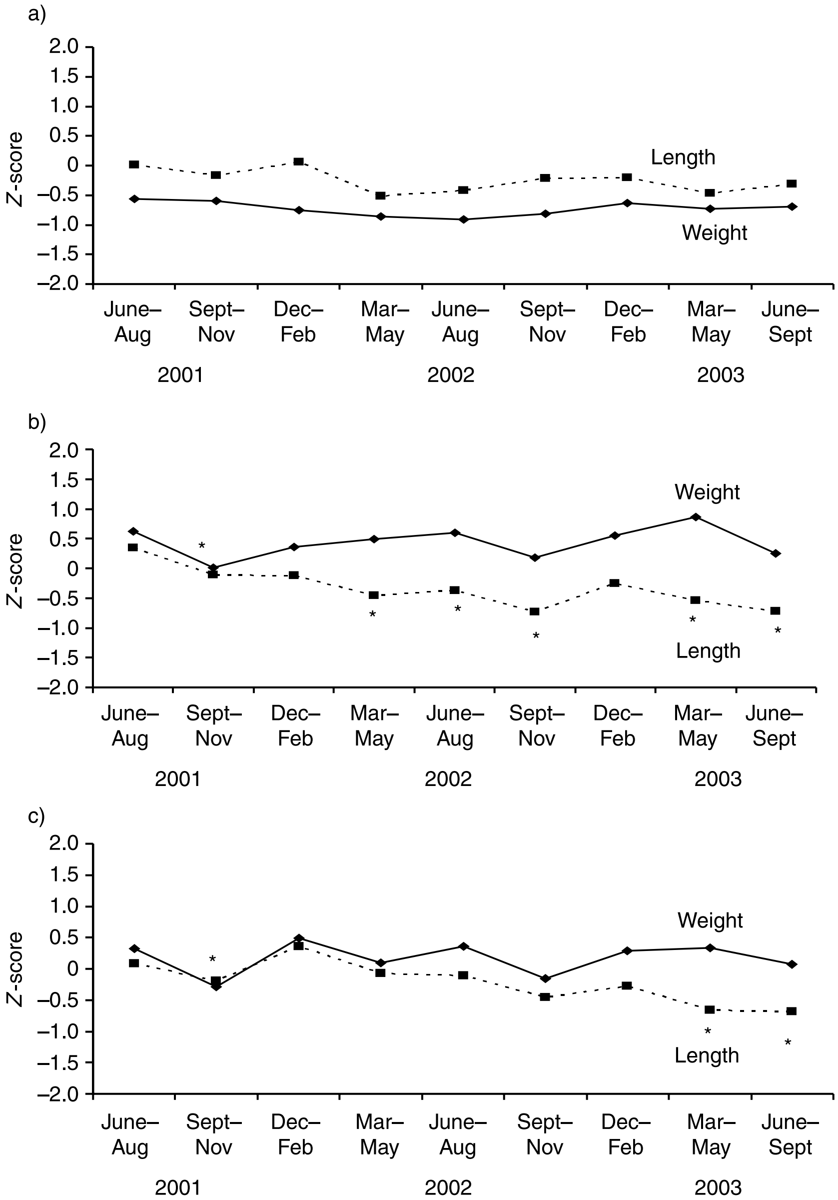

Fig. 2 Infant anthropometric *Z*-scores at birth (a), 6 weeks (b) and 16 weeks (c) by birth date cohort. Each point represents 24–52 measurements. Maize prices were high from January 2002 to April 2003. *P*-values for the effect of cohort in the analyses of variance were, at birth, 6 and 16 weeks, respectively, for weight: 0.32, 0.038 and 0.078; and for length: 0.51, 0.051 and 0.026. *Significant difference compared with the first cohort, $P < 0.05$

significant covariate for all these analyses except birth length, with infected women having smaller infants.

Discussion

A period of increased price of the staple food, maize, had modest effects on plasma vitamin A and E levels of relatively middle-class urban Zambian women with no effect on their mean weight or mean haemoglobin. Such subclinical micronutrient deficiencies are sometimes known as 'hidden hunger'[1] and are not usually considered during food shortage emergencies unless macronutrient deficiencies are present. An adverse effect of higher maize prices was also seen on infant length at 6 and 16 weeks of age. Length decreased throughout the study and thus was lowest for infants who were born after maize prices decreased again and whose mothers had experienced high maize prices during pregnancy.

The nutritional shock to this population appeared milder than that in a similar analysis from Indonesia[5] in which non-pregnant women's body mass index was affected by the increase in food prices. Another difference between our study and the Indonesian analysis is that the sample size in Indonesia was much larger but was based on a series of cross-sectional population sub-samples, whereas ours used a longitudinal cohort. The Indonesian study investigated children under 5 years of age who were eating family foods whereas our study looked at young infants most of whom were exclusively or predominantly breast-fed.

The present analyses were unplanned (as was the drought) and used data collected for a different purpose. Therefore, it is important to consider factors that could influence the validity of the results and conclusions. Samples and questionnaire data were collected, anthropometry conducted and plasma micronutrients were measured by the same small team of midwives and laboratory staff throughout the study. Micronutrients were not analysed exactly in the order of sample collection since they needed to first be transported in batches to London; furthermore, aliquots of the same quality control plasma were used throughout the study and there was no trend to the values found for it. Dietary data were not collected.

Loss to follow-up in the study was fairly low and apparently unbalanced only with respect to maternal HIV status, which was controlled for in all analyses. Although numbers of infant deaths and subjects moving out of the area were too low to be analysed according to the time intervals with respect to maize prices, it was noticed that there was a cluster of infant deaths around the time when the maize price increases had lasted over a year; five of the total 21 infant deaths in the study occurred among the 46 women recruited between March and May 2003. It is possible that these mother–infant pairs were among the most food-insecure and perhaps if they could have been included in the analyses of week 6 and 16 results, the effects seen would have been larger.

Liver stores buffer plasma vitamin A levels and fat stores plasma vitamin E, so that, in a previously reasonably well-nourished population – as this one was based on maternal height, weight and micronutrient markers – effects may not be seen for some time after the beginning of maize price increases. This may be the reason why only modest effects were seen for maternal plasma vitamins A and E. It is possible that no effects of maize price increase were seen for haemoglobin because liver stores could have supplied iron for haem synthesis.

The progressive decrease in infant length *Z*-scores at 6 and 16 weeks without an effect on birth length is of interest regarding the timing of the development of stunting. Our results support the hypothesis that stunting results in part from prenatal insults[18]. Infants born after maize prices had decreased again were the shortest; maize prices would have been high for at least part of the gestation of all these infants. The differences in length *Z*-scores of 1.06 at 6 weeks and 0.77 at 16 weeks between the first and last birth cohorts translate into length differences of 18 mm and 5 mm, respectively, and are large enough to be of public health importance. It is important to note that, as the primary study was concerned with breast-feeding, women were given excellent lactation counselling and support and all infants in the present analysis were exclusively or predominantly (usually just breast milk plus water) breast-fed through most of the follow-up. This indicates that optimal infant feeding practice was unable to overcome the *in utero* insult.

Although we found decreases in maternal micronutrient status which were associated with decreased infant growth after the food shortages, we cannot conclude that these nutritional deficiencies caused the poor growth. Maternal weight and markers of infection were not significantly affected by the maize price increases but it is possible that other unmeasured factors, including deficiencies of other micronutrients which are not buffered by body stores, could have been responsible for the decreased infant growth. It has recently been shown that there are long-term changes in body composition of rats whose dams were deprived of vitamins during pregnancy[19]. Our results suggest that trials investigating the benefits of maternal micronutrient supplementation on infant outcomes should follow infants beyond birth since the effects on later anthropometry were larger than on anthropometry at birth.

Our results provide evidence for the rest of the iceberg of malnutrition which results from food shortages. Although these middle-class women were not of lower weight when the staple food increased in price, they did have lower levels of some micronutrients. More importantly, their infants, although exclusively or predominantly breast-fed, were shorter if their *in utero* or early postnatal life was during the period of high maize prices. The results suggest that a broader aid response, reaching more than the destitute and visibly malnourished, is required during such food shortages. One possibility would be to provide cheap multiple-micronutrient supplements even to people, especially pregnant women, not receiving bulk food aid. The results also support current efforts towards supplementation of pregnant women with more micronutrients than just iron and folate in order promote maternal and infant health.

Acknowledgements

The authors are grateful to Francis Kasolo, Christine Kaseba and Susan Murray for input into supervision of the main study; to William Phiri, Katie Newens and Laura Hindle for excellent laboratory assistance; to all the midwives in Chilenje clinic, especially Molly Chisenga, Esther Simwanza and Loveness Chilala for follow-up and care of study subjects; and to Hildah Mabuda and John Chobo for administrative and logistic assistance. We are grateful to the Wellcome Trust for funding the study; the Trust was not directly involved in the study and is not responsible for the work described. This work was undertaken in collaboration with Great Ormond Street Hospital for Children NHS Trust that receives a proportion of its funding from the NHS Executive.

References

1 Underwood BA. *Perspectives from micronutrient malnutrition elimination/eradication programmes* [online], 2004. Available at http://www.emro.who.int/nfs/Nutrition-MicronutrientMalnutrition-Perspectives.htm. Accessed December 2004.

2 Famine Early Warning Systems Network. Available at http://www.fews.net/centers/current/monthlies/report 2004. Accessed December 2004.

3 Foster P, Leathers HD. Purchasing power: income and the price of food. In: *The World Food Problem: Tackling the Causes of Undernutrition in the Third World*. Boulder, CO and London: Lynne Rienner, 1999; 117–40.

4 Tiffin R, Dawson PJ. The demand for calories: some further estimates from Zimbabwe. *Journal of Agricultural Economics* 2002; **53**: 221–32.

5 Block SA, Kiess L, Webb P, Kosen S, Moench-Pfanner R, Bloem M, *et al*. Macro shocks and micro outcomes: child nutrition during Indonesia's crisis. *Economics and Human Biology* 2004; **2**: 21–44.

6 Serlemitsos JA, Fusco H. *Vitamin A fortification of sugar in Zambia* [online], 2001. Available at http://www.mostproject.org/PDF/zambiasugar. Accessed October 2003.

7 Fylkesnes K, Musonda RM, Sichone M, Ndhlovu Z, Tembo F, Monze M. Declining HIV prevalence and risk behaviours in Zambia: evidence from surveillance and population-based surveys. *AIDS* 2001; **15**: 907–16.

8 Chisenga M, Kasonka L, Makasa M, Sinkala M, Chintu C, Kaseba C, *et al*. Factors affecting the duration of exclusive breastfeeding among HIV-infected and -uninfected women in Lusaka, Zambia. *Journal of Human Lactation* 2005; **21**: 266–75.

9 Erhardt JG, Mack H, Sobeck U, Biesalski HK. β-Carotene and α-tocopherol concentration and antioxidant status in buccal mucosal cells and plasma after oral supplementation. *British Journal of Nutrition* 2002; **87**: 471–5.

10 Gibson RS. *Principles of Nutritional Assessment*. Oxford: Oxford University Press, 1990.

11 Horwitt MK, Harvey CC, Dahm CH Jr, Searcy MT. Relationship between tocopherol and serum lipid levels for determination of nutritional adequacy. *Annals of the New York Academy of Sciences* 1972; **203**: 223–36.

12 Filteau SM, Morris SS, Abbott RA, Tomkins AM, Kirkwood BR, Arthur P, *et al*. Influence of morbidity on serum retinol of children in a community-based study in northern Ghana. *American Journal of Clinical Nutrition* 1993; **58**: 192–7.

13 Friis H, Gomo E, Nyazema N, Ndhlovu P, Krarup H, Kaestel P, *et al*. Maternal body composition, HIV infection and other predictors of gestation length and birth size in Zimbabwe. *British Journal of Nutrition* 2004; **92**: 833–40.

14 Cole TJ, Freeman JV, Preece MA. British 1990 growth reference centiles for weight, height, body mass index and head circumference fitted by maximum penalized likelihood. *Statistics in Medicine* 1998; **17**: 407–29.

15 Tietz NW. *Clinical Guide to Laboratory Tests*, 3rd ed. Philadelphia, PA and London: Saunders, 1995.

16 Sapin V, Alexandre MC, Chaib S, Bournazeau JA, Sauvant P, Borel P, *et al*. Effect of vitamin A status at the end of pregnancy on the saturation of retinol binding protein with retinol. *American Journal of Clinical Nutrition* 2000; **71**: 537–43.

17 Thurnham DI, McCabe GP, Northrop-Clewes CA, Nestel P. Effects of subclinical infection on plasma retinol concentrations and assessment of prevalence of vitamin A deficiency: meta-analysis. *Lancet* 2003; **362**: 2052–8.

18 Shrimpton R, Victora CG, de Onis M, Lima RC, Blossner M, Clugston G. Worldwide timing of growth faltering: implications for nutritional interventions. *Pediatrics* 2001; **107**: E75.

19 Venu L, Harishankar N, Krishna TP, Raghunath M. Maternal dietary vitamin restriction increases body fat content but not insulin resistance in WNIN rat offspring up to 6 months of age. *Diabetologia* 2004; **47**: 1493–501.