Inadequate intakes of dietary zinc among pregnant women from subsistence households in Sidama, Southern Ethiopia

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Abstract

Objective: To assess the prevalence of zinc inadequacy based on dietary intakes and plasma zinc concentrations and, simultaneously, the prevalence of inadequate intakes of energy, protein, calcium and iron.

Design: A cross-sectional study of a convenience sample of subsistence farming households in Sidama, Southern Ethiopia.

Subjects: Dietary intakes were calculated from 1-day weighed food records and 40 repeats from 99 pregnant women in the third trimester using analysed values of major staple foods for zinc, iron, calcium and phytate. The distribution of observed intakes was adjusted for usual intakes and the prevalence of inadequacy estimated using the estimated average requirement (EAR) cutpoint method. Prevalence of inadequacy for zinc, protein and iron intakes were compared with those based on biochemical measures.

Results: Prevalence of zinc inadequacy was very high: 99% for US FNB EAR and 100% for IZiNCG EAR compared to 72% based on low plasma zinc concentrations. Corresponding prevalence estimates for iron were much lower: 4% for inadequate intakes based on US FNB EAR vs. 8.7% for iron deficiency anaemia (haemoglobin $< 110 \, \mathrm{g} \, \mathrm{l}^{-1}$; ferritin $< 12 \, \mu \mathrm{g} \, \mathrm{l}^{-1}$) and 32.3% for low storage iron. Prevalence of inadequacy for protein was 100% for adjusted intakes and 91% for serum albumin $< 32 \, \mathrm{g} \, \mathrm{l}^{-1}$. For calcium, 74% were at risk for inadequate intakes.

Conclusion: The high prevalence of inadequate intakes of zinc and protein was reasonably consistent with those based on biochemical measures. Such dietary deficits could be overcome by regular consumption of cellular animal protein. In contrast, both dietary and biochemical measures of iron inadequacy were low.

Inadequate intakes of dietary zinc have been identified as a major factor in the aetiology of zinc deficiency in developing countries[1]. Such inadequacies may arise from low intakes of zinc *per se* and/or poor bioavailability of dietary zinc. However, quantitative data on zinc intakes of population groups in developing countries at risk to zinc deficiency are limited, in part because of the paucity of data on the zinc content of indigenous staple foods. Substitution of zinc values for staple foods grown in Western countries is not advisable because the zinc content of plant-based foods tends to reflect local soil zinc levels[2,3].

Poor bioavailability of dietary zinc is associated with plant-based diets high in phytate, a potent inhibitor of zinc absorption[4]. Phytate forms insoluble complexes in the gastrointestinal tract with zinc; these complexes cannot be

digested or absorbed because of the absence of intestinal phytase enzyme in humans[5]. Indeed, the relative bioavailability of zinc depends mainly on the phytate : zn ratio of the diet[1].

Certain household food preparation and processing practices (e.g. fermentation, germination and soaking) can reduce the phytate content of plant foods[6], and thus may lead to some improvement in the bioavailability of zinc from plant-based diets. This reduction may be important in diets consumed in Southern Ethiopia, where two of the major dietary staples consumed – starchy foods based on enset (*Enset ventricosum*) and *enjera* prepared from teff (*Eragrotis teff*) – are fermented.

During pregnancy, zinc requirements are especially high because zinc is essential for growth and development of

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the foetus and maternal tissue accretion[7]. Whether the dietary zinc intakes of women in rural Southern Ethiopia are sufficient to meet these high requirements during pregnancy has not yet been established. Zinc deficiency has been associated with adverse effects on both maternal health and pregnancy outcome in some studies, specifically pregnancy complications, reduced birth weight and congenital anomalies[8–10].

In light of the plant-based diets consumed by subsistence farming households in rural Southern Ethiopia, we hypothesised that pregnant women may be especially at risk of inadequate intakes of dietary zinc. To our knowledge, however, there have been no community-based studies focusing on the zinc status of pregnant Ethiopian women. Therefore, the current study aimed to (1) quantify the zinc and phytate intakes, and the phytate : Zn molar ratios of the diets of a self-selected group of subsistence pregnant women living in Sidama province, Southern Ethiopia and (2) examine the relationship between the prevalence of inadequate zinc intakes and low plasma zinc concentrations. In addition, the adequacy of the dietary intakes of energy, protein, calcium and iron was also assessed.

Methods

Participants

The subjects of this cross-sectional study were a convenience sample of women aged 27.8 ± 4.6 years (mean ± standard deviation, SD) from subsistence farming households living in three rural communities (Alamura, Kurda and Fincawoa) located in Sidama zone in the Rift Valley lowlands of Southern Ethiopia. All the women were in the third trimester of pregnancy, based on an assessment of fundal height (Table 1) performed by nurses from the prenatal outreach programme of the nearby Busholo Health Center. The study was conducted during the rainy season in July 2004.

Verbal consent was obtained from all the participants after the nature of the study had been fully explained to

Table 1 Selected demographic, anthropometric and some household food security characteristics of subsistence pregnant women ($n = 99$) from Sidama

	Mean (SD) or %
Age (years)	27.8 (4.6)
Fundal height (cm)	7.1 (1.0)
No schooling (%)	76.8
Gravida: three or less (%)	48.0
Gravida: four to six (%)	36.7
Gravida: seven to eleven (%)	15.3
Weight (kg)	52.1 (6.1)
Height (cm)	154.8 (6.5)
HAZ	−1.48 (1.1)
BMI (kg m^{-2})	21.7 (2.0)
Rarely had enough food to eat (%)	37.4
Sometimes or rarely had enough food to eat (%)	98.0

SD – standard deviation; HAZ – height-for-age *Z*-score; BMI – body mass index.

them, and witnessed by a local health worker or community leader. The study protocol was approved by the Human Ethics Committee of Debub University, Awassa, Ethiopia, and the COMIRB of the University of Colorado, Denver, USA.

Data on sociodemographic characteristics were collected through personal interviews and observations using a pretested questionnaire. All interviews were conducted by trained research assistants who were fluent in both the local language (Sidamigno) and Amharic, and had a good understanding of English. Weight and height of each respondent were measured at the beginning of the survey using standardised techniques and calibrated equipment[11], with the subjects wearing light clothing and no shoes.

Assessment of dietary intakes

Trained research assistants fluent in the local language collected 1-day weighed food records from each of the women in the household. Weekend days and weekdays were proportionately represented in the final survey to account for any day-of-the-week effects on food and/or nutrient intake. Foods and beverages consumed by the women were weighed using digital scales (2 kg maximum weight, model CS 2000; Ohaus Corporation) accurate to ±1 g. Detailed weighed recipe data were also collected for all the composite dishes consumed on the survey day and used to calculate the weight of the actual ingredients consumed by the respondent, as described by Gibson and Ferguson[12]. Average recipe data were compiled for use when actual recipe data were not available. Women were instructed not to change their normal dietary pattern over the food record day. In addition, duplicate 1-day weighed food records were collected on a second nonconsecutive day from a randomly selected sub-sample ($n = 40$) of the respondents.

A food composition database was compiled to compute the energy and selected nutrient intakes based on the food composition tables for use in Ethiopia[13,14]. Additionally, some literature values[15] and analysed calcium, zinc, iron and phytate values for representative staple foods collected from the households and local markets[16] were also used. Crude fibre values in the Ethiopian food composition tables were replaced by total dietary fibre values from the World Food Dietary Assessment System[17]. Median (1st and 3rd quartile) intakes (per day; per MJ) and the major food sources of energy, nutrients, dietary fibre and phytate were calculated from the coded 1-day weighed food records. Foods and beverages were classified into eight major food groups.

Observed energy intakes were adjusted for digestibility by 0.95[18] and protein intakes for digestibility and amino acid score by 0.68[19,20] to take into account the high intakes of dietary fibre and the very low content of animal-source foods in the diets of the study participants

in Sidama, Southern Ethiopia. Iron intakes were not adjusted for the enhancing effects of either ascorbic acid or cellular animal protein because intakes of these were either very low or non-existent.

Assessment of the prevalence of low biochemical indices of zinc, iron and protein status

Non-fasting morning venepuncture blood samples were collected from the participants in the sitting position during clinics held in the open-air Alamura community center. Blood was drawn using syringes (Becton-Dickenson), and then transferred into trace-element-free heparinised Eppendorf tubes (Biorad), which were stored in a cooler. One aliquot of this freshly collected anti-coagulated whole blood was used for a complete blood cell count performed by an electronic counter in the nearby Bushulo Health Center. A second aliquot was separated within 2 h using trace-element-free techniques based on the recommended procedures of the International Zinc Nutrition Consultative Group (IZiNCG)[1], and the plasma stored frozen at $-20°C$ in trace-element-free polypropylene vials. The frozen plasma samples were hand-carried by K.M.H. to the University of Colorado Health Science Center for analysis. Plasma zinc was analysed by flame atomic absorption spectrophotometry, as described elsewhere[21]. Plasma ferritin and C-reactive protein (CRP) were assayed by nepholometry (Dade Behring BNII Automated Nepholometer) at the General Clinical Research Center, Denver, CO, and plasma albumin by spectrophotometry. Plasma CRP was used to indicate the presence of infection or inflammation[22]. Women with elevated plasma CRP (i.e. $\geq 5 \, \text{mg} \, \text{l}^{-1}$) were excluded from the statistical analyses.

The precision and accuracy of all the biochemical assays were checked using appropriate manufacturer's controls or a certified reference material for zinc (Bovine Serum Reference Material #1590; National Institute of Standards and Technology). For plasma ferritin, CRP and albumin, values for the manufacturer's controls fell within the certified ranges. Coefficients of variation (CV) for the low, medium or high controls for serum ferritin were 8.6%, 3.1% and 4.0%, and 4.1%, 7.1% and 5.6% for CRP, respectively. For plasma albumin, the CV for the low and high controls (Liquichex; Biorad) were 0.8% and 1.0%, respectively. For plasma zinc, the mean value (SD, CV%) was 13.66 (1.9, 2.1%) compared with the certified value of 13.62 (6.0, 6.7%) $\mu \text{mol} \, \text{l}^{-1}$.

The prevalence of zinc deficiency (in the absence of infection or inflammation) was defined by the IZiNCG cutoff values for plasma zinc for women in the third trimester of pregnancy[1]. Likewise, for iron deficiency anaemia, a combination of low haemoglobin ($<110 \, \text{g} \, \text{l}^{-1}$)[23] and low plasma ferritin concentrations (i.e. $<12 \, \mu \text{g} \, \text{l}^{-1}$)[24] in the absence of infection or inflammation was used. This same cutoff value for plasma ferritin was used to indicate the prevalence of low iron stores.

Statistical analysis

Statistical analyses were carried out using SPSS version 8.0 (SPSS Inc.). All variables were tested for normality using the Kolmogorov–Smirnov test. Dietary results are expressed in terms of the median and interquartile range because the intakes of several nutrients were not normally distributed. Correlations between dietary intake measures were examined using Spearman's rank correlation test.

Before assessing the prevalence of inadequate intakes, the observed distributions of 1-day intakes were adjusted to remove the variability introduced by day-to-day variation in nutrient intakes within an individual (i.e. to remove the within-subject variation). This adjustment was achieved by using the nutrient intake data from the 40 repeated 1-day food records and the computer program PC-Side[25].

Estimates of the prevalence of inadequate intakes for zinc, protein, calcium and iron were calculated using the estimated average requirement (EAR) cutpoint method[26] using estimates of the average requirements for each nutrient of interest and the 'usual intake' distributions from PC-Side. For zinc, the EARs for pregnancy set by the US Food and Nutrition Board (FNB)[7] and by IZiNCG[1] were used. For protein and calcium, estimates of the mean requirements for pregnancy compiled by Bunch and Murphy[17], and based on those set by international agencies, were used[19,27]. For iron, the EAR for pregnancy set by the US FNB[7] was applied because an EAR for iron has not been given in the revised Food and Agriculture Organization of the United Nations (FAO)/ World Health Organization (WHO) requirement estimates[27].

Energy intakes adjusted for digestibility were compared to the revised energy requirement for pregnancy by FAO[18]. The average energy requirement of the group was calculated from the mean basal metabolic rate (BMR) multiplied by the average physical activity level (PAL). The BMR was predicted from standard age- and sex-specific equations based on the mean body weight of the women in the third trimester of pregnancy adjusted for prepregnant weight by assuming an average gestational weight gain of 12 kg. A value for habitual PAL (mid-point of the moderately active lifestyle) was used for this group of subsistence farmers, as recommended by FAO[18]. An additional $2.0 \, \text{MJ} \, \text{day}^{-1}$ was added to take into account the additional energy cost of the third trimester of pregnancy[18].

Results

Characteristics of study population

The characteristics of the study population are shown in Table 1. The self-reported age (mean ± SD) of the women was 27.8 ± 4.6 years. All the women were subsistence farmers; 76.8% ($n = 76$) had no formal education and only 10% ($n = 10$) had four or more years of schooling.

Almost all of the women lived in houses made of mud walls with thatched roofs, no windows and a shared latrine.

Of the women, 11.1% and 4.1% had a height below 148 and 145 cm, respectively, and 30% ($n = 30$) were stunted (i.e. height-for-age Z-score (HAZ) < -2SD). The number of pregnancies ranged from one to eleven (mean $\pm$ SD; 4.1 ± 2.5). Of the women, 48% ($n = 47$) had 0–3 pregnancies, 36.7% ($n = 36$) had 4–6 pregnancies and 15.3% ($n = 15$) had 7–11 pregnancies. In relation to food security, 98% of the women responded that they only sometimes or rarely had enough to eat, and over 90% reported they had not eaten meat or fish since the Easter holiday, even though the survey was undertaken in July.

Dietary assessment

Median (1st, 3rd quartile) dietary intakes (per day and per MJ) are shown in Table 2. Major food sources of energy, protein, zinc, iron and calcium are presented in Table 3. Cereal grains (mainly unrefined maize) contributed the major source of energy, protein, iron and zinc, whereas starchy foods prepared from enset (*E. ventricosum*) (mainly *kocho*) were the primary source of calcium and the secondary source of iron. Vegetables (mainly Ethiopian kale, *Brassica carinata braun*) provided the secondary source of calcium. Intakes of animal protein were very low; less than 1% of energy intake was provided by dairy products, mainly cow or goat milk, and no cellular animal foods were eaten. As a result, the haem iron content of the diets was zero. The dietary diversity score in Sidama was very low – 75.8% of the subjects consuming four or fewer types of foods per day.

Estimated energy intakes of these subsistence pregnant women were very low: all the women had adjusted energy intakes below the FAO[18] mean energy requirement estimate; 95% had intakes below two-thirds of this requirement. For zinc, 99% of the women had inadequate intakes based on the US FNB EAR for zinc (i.e. 9.5 mg day^{-1})[7], and all the women (i.e. 100%) had inadequate zinc intakes when the IZiNCG EAR cutoff of 12 mg day^{-1} was used[1]. The latter EAR cutoff was selected, based on our analysed median phytate : Zn molar ratio of the diet (i.e. 18.6) (Table 2). The prevalence of inadequate intakes of protein and calcium was 100% and 74%, respectively, based on the EARs compiled by Bunch and Murphy[17] from the corresponding requirements for pregnancy set by international agencies[19,27]. In marked contrast, relatively few women (i.e. 4%) were at risk of inadequate intakes of iron, using the EAR for iron set by the US FNB (i.e. 22 mg day^{-1})[7].

Prevalence of low biochemical measures of zinc, iron and protein status

Table 4 presents the proportion of women with low biochemical indices of zinc, iron (in the absence of infection/inflammation) and protein status. Of the three nutrients, the estimated prevalence of low biochemical status was highest for protein, followed by zinc; iron deficiency anaemia (based on a low haemoglobin and low plasma ferritin) had the lowest prevalence (8.7%).

Discussion

The zinc intakes of the pregnant women of this study were very low, and below those reported in many other developing countries, including other countries in Africa[28–30]. Low energy intakes were partly responsible for these low zinc intakes; as one might expect, energy and zinc intakes were positively correlated ($r = 0.86$; $P < 0.001$). Another contributing factor was the relatively high proportion of energy ($\sim 32\%$) provided by enset

Table 2 Median (1st, 3rd quartiles) of energy, selected nutrients, dietary fibre, phytate and phytate : Zn and phytate : Fe molar ratios (per day; per MJ) of subsistence pregnant women ($n = 99$) from Sidama

	Median (1st, 3rd quartiles) intakes per day	Median (1st, 3rd quartiles) intakes per MJ
Adjusted energy* (kJ)	3981 (3156, 5211)	
Utilizable protein† (g)	15.5 (10.4, 20.1)	3.8 (3.3, 4.3)
Fat (g)	7.7 (4.7, 11.7)	2.0 (1.5, 2.7)
Carbohydrate (g)	231.2 (178.2, 299.7)	57.7 (56.4, 58.6)
Ca (mg)	479 (220, 680)	120 (59, 170)
Fe (mg)	27.1 (20.7, 33.2)	6.5 (6.2, 7.4)
Zn (mg)	5.0 (3.3, 7.2)	1.3 (1.1, 1.5)
Ascorbic acid (mg)	2.2 (0.8, 4.7)	0.56 (0.18, 1.3)
Total dietary fibre (g)	24.4 (15.3, 32.8)	6.3 (4.7, 7.1)
Phytate (mg)	1011 (528, 1575)	253 (140, 375)
[Phytate] : [Zn]‡	18.6 (13.1, 23.6)	
[Phytate] : [Fe]‡	3.13 (1.73, 4.82)	

* Adjusted for digestibility.
† Adjusted for digestibility and amino acid score.
‡ Molar ratio.

Table 3 Mean percentage of energy, protein and zinc intakes provided by eight major food groups for subsistence pregnant women ($n = 99$) from Sidama

	Cereals	Enset foods	Legumes	Dairy	Vegetables	Fruit	Oil	Beverages
Energy	58.7	29.7	3.9	0.4	3.3	0.1	0.2	3.2
Protein	56.7	11.9	10.5	1.6	11.8	0.0	0.0	7.4
Zinc	70.2	13.3	6.9	1.0	8.1	0.0	0.0	0.5
Iron	48.6	33.5	2.8	0.1	11.1	0.1	0.0	3.9
Calcium	9.2	47.4	2.8	2.9	28.6	0.1	0.0	8.4

Table 4 Prevalence of low measures of zinc, iron and protein for subsistence pregnant women from Sidama

Measure	Number of subjects	Prevalence of low values (%)*
Plasma Zn $< 7.6\,\mu mol\,l^{-1}$	94	71.7
Haemoglobin $< 110\,g\,l^{-1}$	93	19.2
Plasma ferritin $< 12\,\mu g\,l^{-1}$	95	32.3
Haemoglobin $< 110\,g\,l^{-1}$ and ferritin $< 12\,\mu g\,l^{-1}$	93	8.5
Plasma albumin $< 32\,g\,l^{-1}$	95	90.9

*In absence of plasma CRP $\geq 5\,mg\,l^{-1}$.

products with a very low zinc content (Table 3). Of these enset products, *kocho* – the fermented pulp of enset baked into bread – was most frequently eaten, followed by *bulla* (white low-fibre desiccated juice from enset pulp)[31]. Analysis of samples of fermented kocho and bulla consumed by these women revealed a zinc content of only 0.56 mg Zn/100 g and 0.07 mg Zn/100 g fresh weight, respectively[16]. Measurements of the quantity of zinc absorbed in a convenience sub-sample of this population[21] demonstrated not only that dietary requirements for zinc were unmet but also that the quantity of zinc absorbed was notably short of physiological requirements. This applied to the less-demanding figure for physiological requirements in late pregnancy of IZiNCG[1] as well as to the figure of the US FNB[7].

The presence of such low zinc intakes is likely to be further exacerbated by the moderately high phytate : Zn molar ratios of the diets of the Sidama households in Southern Ethiopia. This arose because unleavened maize bread, followed by enset starchy foods, were the primary and secondary sources of zinc (Table 3). However, fractional absorption of zinc in a convenience sub-sample of this population[21] was a little higher than that predicted by two models[1,32] for the ingested level of zinc and phytate. Even higher phytate : Zn molar ratios have been reported for the diets of pregnant women consuming unrefined maize-based diets in Malawi[33,34], Nigeria[30] and Guatemala[35]. It should be noted that in our zinc absorption study[21], the phytate effect in inhibiting zinc absorption was not as severe as predicted from published models[1,32]. Understanding of this deviation from the predicted effect will depend on further, more extensive research.

It is noteworthy that these Ethiopian pregnant women had even lower intakes of animal-source foods than those reported during pregnancy in many other developing countries[28,30,36]. Such low intakes of animal protein are likely to be an additional factor compromising zinc (and non-haem iron) absorption in the diets of Sidama households in Southern Ethiopia[37]. Small amounts of cow's milk or goat's milk with coffee were the only source of animal protein consumed, and provided less than 1% of the total energy of the diet (Table 3) compared with about 5% in rural Malawi[28]. This is surprising because most of the households surveyed owned some livestock,

notably goats, cows and chickens. However, they were used mainly as an income-generating activity rather than for home consumption. Further, although the villages were close to Lake Awassa, fish was rarely consumed. Small indigenous fish sources are potentially a rich source of protein and several other nutrients, including calcium and retinol, if eaten whole with bones, and after drying can be powdered and used to enrich porridges based on enset or maize.

In view of the very low zinc intake in association with moderately poor availability that characterises these diets, it is not surprising that there was a high prevalence of inadequate zinc intakes among these women, irrespective of the EAR applied. Indeed, the prevalence estimate appears the highest reported for pregnant women in developing countries to date[28,36], and somewhat higher than the prevalence of low plasma zinc concentrations noted among this population (i.e. 72%) (Table 4). The uncertainty associated with the cutoff for serum zinc concentrations during the third trimester of pregnancy may be partly responsible for this discrepancy. The sample size for pregnant women in the US National Health and Nutrition Examination Survey II data used to establish the lower cutoff for serum zinc concentrations for each trimester of pregnancy was very small (i.e. $n = 61$), limiting the reliability of the 2.5th percentile estimate[1,38].

Unlike zinc, the prevalence of inadequate intake of calcium among these pregnant women from Sidama, Southern Ethiopia, was lower than estimates from several other developing countries[28,36], except for those countries where calcium is ingested from tortillas prepared from lime-soaked maize[35]. Both enset and kale, regular components of these diets, have a relatively high content of calcium, which is probably readily absorbed because neither of these plant-based foods is high in phytates or oxalates, known to inhibit calcium absorption[39]. Nevertheless, it is unlikely that the calcium levels in the diets of these Sidama households are high enough to exacerbate the inhibitory effect of phytate on zinc absorption[37].

It is of interest that, in contrast to zinc, very few of the women were at risk to inadequate intakes of iron, even though iron and zinc usually have a similar distribution in the food supply and are affected by many of the same dietary absorption modifiers[12]. The high content of iron in Ethiopian diets has been emphasised earlier[40,41] and attributed to the consumption of the indigenous cereal teff (*E. teff*), oleaginous seeds and Ethiopian kale (*B. carinata braun*), all foods that appear to contain relatively high levels of iron[13,14,42]. In these Sidama households, however, cereals, notably unrefined high-phytate corn-bread, contributed to almost 50% of the dietary iron, followed by starchy enset products (34%); vegetables, predominantly kale, provided only 11% of the total dietary iron (Table 3).

Some investigators have linked the high iron intakes by population groups in Ethiopia to contaminant iron from soil rather than to iron intrinsic to food[40,43]. The highly variable iron content of samples of fermented *kocho* consumed by these pregnant women and analysed in our laboratory[16], and the preparation of *kocho* by fermenting enset pulp in earth pits[31,44], both support this suggestion.

Whether contaminant iron joins the common non-haem iron pool (i.e. is exchangeable) and is thus available for absorption has not been firmly established because predicting the exchangeability of contaminant iron is difficult[45]. Very few of the study participants ($\sim 8\%$) had any evidence of iron deficiency anaemia in later pregnancy, and only about one-third had depleted iron stores (Table 4), even though supplements of iron–folate were rarely consumed by pregnant women in these three villages. Several other reports have indicated that nutritional iron deficiency is not a serious problem in Ethiopia, even during pregnancy when iron requirements are high[41].

Our findings show a reasonable concordance between dietary and biochemical measures of iron inadequacy among this group of pregnant Ethiopian women, given that the EAR used assumed 25% absorption of iron. Whether the absence of nutritional iron deficiency can be attributed to up-regulation of iron absorption in late pregnancy in response to the increased demand, or because at least some of these women had sufficient iron stores when entering pregnancy to maintain an adequate iron balance, is uncertain. We used the EAR for iron set by the US FNB (i.e. 22 mg day^{-1})[7] to calculate the risk of dietary iron inadequacy in this study because FAO[27] did not set an EAR. The US FNB figure for iron absorption during the third trimester of pregnancy (i.e. 25%) may be unrealistically high, given that these Southern Ethiopian diets contain moderately high levels of phytate and probably polyphenols (from the consumption of coffee), are devoid of haem iron and contain low levels of ascorbic acid (Table 2).

The low energy intakes reported here are consistent with the very low mean body mass index of these women during the third trimester of pregnancy (Table 1), suggesting that such low energy intakes are unlikely to be associated with energy underreporting[46]. Indeed, almost all of the women admitted that they only sometimes or rarely had enough to eat (Table 1). Moreover, anecdotal reports indicate that pregnant women in Ethiopia may restrict their energy intake during late pregnancy in an effort to reduce risk of complications during delivery. Certainly, because of their short stature (mean HAZ = −1.48) (Table 1), these women were likely to be at increased risk during delivery as a result of cephalo-pelvic disproportions[47]. Height below 148 cm has also been associated with poor foetal outcomes, and in this study 11.1% of the women had a height below 148 cm[48].

It is possible that such low energy intakes may have a negative effect on protein utilisation[20]. If so, the estimate for risk of inadequate protein intakes may be even higher than 95%. Of the women in this study, 91% had low serum albumin concentrations (in the absence of infection), a proportion consistent with that based on the dietary intakes.

We believe this study has several strengths. The collection of weighed food intakes and samples of staple foods as consumed in the households for chemical analysis enhanced both the accuracy of the portion size estimates and the quality of our food composition data for zinc, iron, calcium and phytate. Moreover, our prevalence estimates for nutrient inadequacies were derived from the distribution of usual intakes. Such estimates were reasonably consistent with those based on biomarkers for zinc, iron and protein status.

We recognise that our results are not based on a representative sample of pregnant women in the third trimester living in the Sidama zone of Ethiopia. Nevertheless, several of the nutritional status variables for these Sidama women were comparable to those reported for the same region in the 2006 Ethiopian Demographic and Health Survey (DHS) (i.e. Southern Nations, Nationalities, and Peoples (SNNP))[49]. For example, in the SNNP region, both the mean height of women aged 15–49 years and the proportion with height <145 cm were very comparable to those reported here (156.3 vs. 154.8 cm; 4.1% vs. 4%, respectively). Further, in the SNNP region, 23.5% of women had anaemia, defined as a haemoglobin ≤110 g l^{-1}, compared with 19.2% in this study. Of the anaemic women in the SNNP region, 14.8%, 7.7% and 10% were classified with mild, moderate or severe anaemia vs. 13%, 7% and 0%, respectively, in our study. Consumption of iron-rich foods in the SNNP region was among the lowest in the Ethiopia DHS survey with 7.9% of women aged 15–49 years compared with 27.3% in Addis Ababa consuming iron-rich foods. In our study, none of the pregnant women had consumed iron-rich foods on the weighed record day.

In summary, this study has highlighted for the first time the very low zinc status of these Sidama pregnant women who consumed diets in which almost a third of the energy was derived from enset (*E. ventricosum*). The latter is a plant-based staple unique to Ethiopia and consumed by more than 20% of the population[31]. This finding is important, because in the past only the low protein content of enset-based diets has been emphasised. Clearly, a public health intervention is urgently required that addresses simultaneously the coexisting energy and nutrient deficits noted here. A possible strategy includes improving overall dietary quality through enhancing intakes of cellular animal protein, an excellent source of high-quality protein, readily available zinc, iron, vitamin B$_{12}$ and, in some cases, vitamin A and calcium. However, to change attitudes and awareness among

households in this setting about the nutritional benefits of animal-source foods, nutrition education based on formative research must be included as an integral part of any food-based intervention.

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