European Journal of Clinical Nutrition (2009) 63, 916–918
 0954-3007/09 $32.00
www.nature.com/ejcn

SHORT COMMUNICATION

Zinc status and cognitive function of pregnant women in Southern Ethiopia

BJ Stoecker[1], Y Abebe[2], L Hubbs-Tait[3], TS Kennedy[1], RS Gibson[4], I Arbide[5], A Teshome[5], J Westcott[6], NF Krebs[6] and KM Hambidge[6]

[1]*Department of Nutritional Sciences, Oklahoma State University, Stillwater, OK, USA;* [2]*Department of Applied Human Nutrition, Hawassa University, Awassa, Ethiopia;* [3]*Department of Human Development and Family Sciences, Oklahoma State University, Stillwater, OK, USA;* [4]*Department of Human Nutrition, University of Otago, Dunedin, New Zealand;* [5]*Bushulo Health Centre, Awassa, Ethiopia and* [6]*Section of Nutrition, Department of Pediatrics, University of Colorado Health Sciences Center, Denver, CO, USA*

The relation between zinc status and cognitive function was examined in a cross-sectional study in the Sidama area of Southern Ethiopia. Pregnant women >24 weeks of gestation from three adjacent rural villages volunteered to participate. Mean (s.d.) plasma zinc of 99 women was 6.97 (1.07) μmol/l (below the cutoff of 7.6 μmol/l indicative of zinc deficiency at this stage of gestation). The Raven's Coloured Progressive Matrices (CPM) test was administered individually. Scores for the Raven's scale A, which is the simplest scale, ranged from 4 to 10 of a possible 12. Women with plasma zinc <7.6 μmol/l had significantly lower Raven's CPM scale A scores than women with plasma zinc concentrations >7.6 μmol/l. Plasma zinc and maternal age and education predicted 17% of the variation in Raven's CPM scale A scores. We conclude that zinc deficiency is a major factor affecting cognition in these pregnant women.
European Journal of Clinical Nutrition (2009) **63,** 916–918; doi:10.1038/ejcn.2008.77; published online 4 February 2009

Keywords: Raven's Coloured Progressive Matrices (CPM); maternal cognition; zinc deficiency; Ethiopia

Introduction

Malnutrition in pregnant women may affect child cognition through its effects on fetal development. Zinc is of particular concern during pregnancy because of its potential effect on fetal brain development (Bhatnagar and Taneja, 2001) and birth outcomes.

Fluid cognitive deficits and impaired working memory have been associated with the hippocampus (Blair, 2006) that has a role in spatial memory and has been suggested to be sensitive to zinc deficiency (Takeda, 2001). Attention may also be affected by zinc deficiency (Bhatnagar and Taneja, 2001). This study used the Raven's Coloured Progressive Matrices (CPM) (Raven, 1984) to examine the relation between zinc status and cognitive abilities of pregnant women from Southern Ethiopia whose dietary intake of zinc, but not iron, is exceptionally low (Abebe *et al*., 2007). The CPM test has been used cross-culturally to evaluate effects of nutrient deficiency on fluid intelligence or problem-solving ability (Beard *et al*., 2005; Zimmermann *et al*., 2006; Neumann *et al*., 2007). The strong association between under-five child mortality rate and low maternal scores on the Raven's CPM emphasizes the importance of maternal cognition for child survival (Sandiford *et al*., 1997).

Subjects and methods

Participants in this cross-sectional study were 99 third-trimester pregnant women (mean age 27.7 (4.7) years) from the Sidama region of Southern Ethiopia. After information sessions, women volunteers returned to the community center and gave verbal consent witnessed by a local community health worker. The study was approved by the Ethics Committee at Hawassa University in Ethiopia and Institutional Review Boards of involved universities in the United States.

Nonfasting morning blood samples were collected by venipuncture in the community centers. Complete blood counts were performed on an electronic counter; plasma was separated within 2 h using methods appropriate for trace

Correspondence: Dr BJ Stoecker, Department of Nutritional Sciences, Oklahoma State University, 301 Human Environmental Sciences, Stillwater, OK 74078, USA.
E-mail: barbara.stoecker@okstate.edu
Received 26 May 2008; revised 30 November 2008; accepted 2 December 2008; published online 4 February 2009

minerals (Hotz and Brown, 2004) and stored at −20 °C until analysed for zinc by atomic absorption spectroscopy and for ferritin and albumin as reported previously (Abebe *et al.*, 2007).

Demographic and socioeconomic variables were determined by interview. Cognitive function was evaluated by individual administration of the Raven's CPM by trained research personnel. A person being tested with the CPM is expected to select correctly, from among six options, the piece to complete a design thereby testing their ability to make comparisons and to reason about similarities. The Raven's scale A, the simplest section of the CPM, consists of 12 designs.

Descriptive data including means, standard deviations, distributions and correlations were compiled. For multiple regression analyses, the stepwise regression procedure (Statistical Analysis System, version 9.1) was used to select among variables identified in the literature and in correlation analyses for prediction of cognitive scores.

Results

Mean (s.d.) plasma zinc was 6.97 (1.07) (45.6 (7.0) μg/100 ml) with 76% of women having values <7.6 μmol/l (50 μg/100 ml), the suggested cutoff for zinc deficiency in the third trimester of pregnancy (Figure 1) (Hotz and Brown, 2004). Iron deficiency was less prevalent with 29% of women having hemoglobin <115 g/l (cutoff adjusted for altitude of 1800 m) and 34% having low iron stores (serum ferritin <12 μg/l).

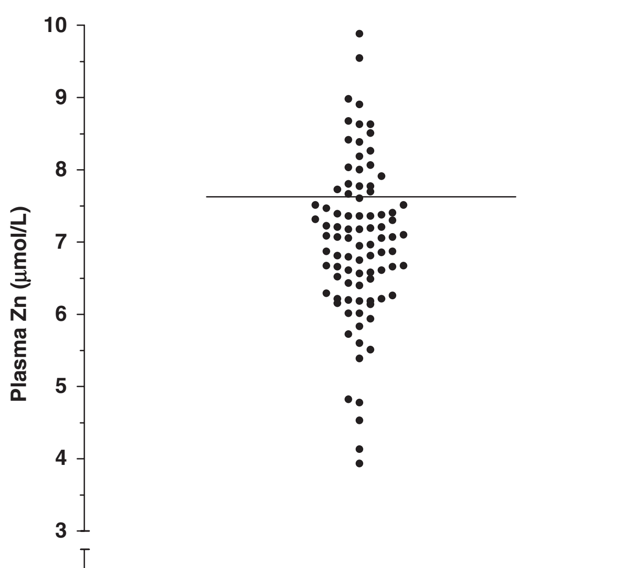

Figure 1 Plasma zinc concentrations of women in third trimester of pregnancy from a rural area in Southern Ethiopia. Seventy-six percent of the women were below the cutoff for deficiency (7.6 μmol/l) for third trimester of pregnancy.

All families were subsistence farmers; 77% of the women had no formal education and only 10% had attended school for four or more years. Most women lived in houses with mud walls and thatched roofs and 37% reported that they rarely had enough food to eat (Abebe *et al.*, 2007).

Scores on the Raven's CPM scale A (CPM (A)) ranged from 4 to 10. Relations between CPM (A) and social and nutritional variables are presented in Table 1. Although most variables did not correlate with the cognitive tests, the CPM (A) score was correlated with plasma zinc ($r = 0.27$, $P < 0.008$). Furthermore, the mean (s.d.) CPM (A) score of 7.1 (1.2) for women with plasma zinc >7.6 μmol/l was higher ($P < 0.04$) than the score of 6.5 (1.3) for women with plasma zinc <7.6 μmol/l. The CPM (A) score was not significantly correlated with serum albumin or ferritin. Using multiple regression analysis, the combination of plasma zinc and maternal age and education predicted 17% of the variation in Raven's CPM scale A scores (Table 2).

Discussion

The extremely low plasma zinc concentrations reflected the women's very low median zinc intake of 5.0 mg per day, with a phytate:zinc molar ratio averaging 18.6 (Abebe *et al.*, 2007) and inadequate absorption (Hambidge *et al.*, 2006). Plasma zinc concentrations accounted for 8% of the variation in CPM (A) scores. Dietary zinc was primarily from maize with

Table 1 Pearson correlation coefficients for selected cognitive, demographic and nutritional variables of pregnant women in the third trimester in Sidama, Ethiopia

Variable	*RavA*	*Age*	*Food security*	*Education*	*Albumin*	*Ferritin*	*Zinc*
RavA	1.00	0.29*	−0.02	0.10	0.19	−0.15	0.27*
Age		1.00	−0.17	−0.30*	−0.05	−0.05	−0.04
Food security			1.00	0.01	−0.01	0.00	0.04
Education				1.00	0.02	−0.02	−0.02
Albumin					1.00	0.08	0.28*
Ferritin						1.00	−0.11
Zinc							1.00

$n = 99$ (except ferritin $n = 85$ and age $n = 98$).
*$P < 0.01$.

Table 2 Multiple regression analysis predicting Raven's CPM scale A scores in pregnant women in Sidama, Ethiopia

	B	*s.e.*	P-*value*
Intercept	1.432	1.115	0.2022
Zinc	0.340	0.111	0.0028
Age	0.099	0.027	0.0004
Education	0.159	0.082	0.0569

Adjusted $R^2 = 0.168$, $P = 0.001$, $n = 98$.
Additional variables tested in the stepwise multiple regression procedure and found not to be significant were: food security, albumin, hemoglobin and ferritin.

no meat. Feeding meat, which is the best dietary source of zinc, to Kenyan preschool children has resulted in a striking improvement in Raven's CPM (Neumann *et al*., 2007).

Because the Raven's CPM reflects the functional ability of the mother, the contribution of age as a predictor of that score may represent the wisdom acquired with age from better educated people in the community by illiterate women. Formal education of the mother predicted an additional 3% of the variation in Raven's CPM (A) scores.

Effects of iron deficiency on cognition are well established (Beard *et al*., 2005) but in our study, the scores on the CPM (A) were not correlated with iron status. No measure of iron made a significant contribution to the regression model suggesting that the impaired cognitive function was not due to iron deficiency.

Bhargava and Fox-Kean (2003) found that although maternal education did not significantly predict children's dietary intakes, maternal scores on cognitive tests were associated with children's pattern of food intake. Likewise, Sandiford *et al*. (1997) related maternal CPM scores and under-five child mortality. Scores for our women were extremely low compared to African norms (Neumann *et al*., 2007).

A limitation of this study is that cross-sectional data cannot determine cause and effect; thus, further investigation of nutritional and psychosocial correlates of the dramatically low Raven's CPM scores in these rural communities is important to further define the basis for our findings. However, if functional ability of the mother is closely related to adequate child nutrition (Bhargava and Fox-Kean, 2003), addressing nutrient deficiencies that impair maternal cognitive function must be a priority for development.

Acknowledgements

We acknowledge assistance of Sidama and Bushelo Health Center community workers. We thank Elsa and Mebrat, Carolyn Hambidge and study participants. Research support from Fogarty International Center (R21_TW006729) and Office of Dietary Supplements, NIH, and from GCRC M01 RR00069 and NIH MRDDR Center Grant (P30 HD004024) is also acknowledged.

References

Abebe Y, Bogale A, Hambidge KM, Stoecker BJ, Arbide I, Teshome A *et al*. (2007). Inadequate intakes of dietary zinc among pregnant women from subsistence households in Sidama, Southern Ethiopia. *Public Health Nutr* **11**, 379–386.

Beard JL, Hendricks MK, Perez EM, Murray-Kolb LE, Berg A, Vernon-Feagans L *et al*. (2005). Maternal iron deficiency anemia affects postpartum emotions and cognition. *J Nutr* **135**, 267–272.

Bhargava A, Fox-Kean M (2003). The effects of maternal education versus cognitive test scores on child nutrition in Kenya. *Econ Hum Biol* **1**, 309–319.

Bhatnagar S, Taneja S (2001). Zinc and cognitive development. *British J Nutr* **85**, S139–S145.

Blair C (2006). How similar are fluid cognition and general intelligence? A developmental neuroscience perspective on fluid cognition as an aspect of human cognitive ability. *Behav Brain Sci* **29**, 109–125.

Hambidge KM, Abebe Y, Gibson RS, Westcott JE, Miller LV, Lei S *et al*. (2006). Zinc absorption during late pregnancy in rural Southern Ethiopia. *Am J Clin Nutr* **84**, 1102–1106.

Hotz C, Brown KH, International Zinc Nutrition Consultative Group (IZiNCG) (2004). Assessment of the risk of zinc deficiency in populations and options for its control. *Food Nutr Bull* **25**, S91–S202.

Neumann CG, Murphy SP, Gewa C, Grillenberger M, Bwibo NO (2007). Meat supplementation improves growth, cognitive, and behavioral outcomes in Kenyan children. *J Nutr* **137**, 1119–1123.

Raven JC (1984). *Manual for the Coloured Progressive Matrices (Revised)*. NFER-Nelson: Windsor, UK.

Sandiford P, Cassel J, Sanchez G, Coldham C (1997). Does intelligence account for the link between maternal literacy and child survival? *Soc Sci Med* **45**, 1231–1239.

Takeda A (2001). Zinc homeostasis and functions of zinc in the brain. *Biometals* **14**, 343–351.

Zimmermann MB, Connolly K, Bozo M, Bridson J, Rohner F, Grimci L (2006). Iodine supplementation improves cognition in iodine-deficient schoolchildren in Albania: a randomized, controlled, double-blind study. *Am J Clin Nutr* **83**, 108–114.