J Community Nutrition 6(2) : 97~102, 2004

□ Original Article □

Association between Vitamin C Nutritional Status and Blood Lead Level in Korean Male Lead Workers

Hee-Seon Kim†

Department of Food Science and Nutrition, Soonchunhyang University, Asan, Korea

ABSTRACT

A cross-sectional epidemiologic study was conducted to evaluate vitamin C nutritional status by assessing dietary intake and blood vitamin C level and to identify the relationships between dietary vitamin C intake, serum vitamin C level and blood lead level in Korean lead workers. The study population was 118 lead workers from two battery manufacturing factories and 63 non-lead-exposed controls. A food consumption survey was conducted by the 24-hr recall method to determine the dietary vitamin C intake level. The anthropometric measurements, blood collection, and survey were performed between September and November, 2000. Blood lead levels and serum vitamin C levels were measured using an atomic absorption spectrometer and high performance liquid chromatography, respectively. Vitamin C nutritional status of Korean lead workers was lower than that of the control group, in terms of both dietary intake and the biochemical index : the mean daily dietary intake level of vitamin C of lead workers was 65.9mg (94% RDA), while that of controls was 132.6mg (189% RDA) ; and the serum vitamin C status of lead workers (0.10mg/dl) was significantly lower than that of controls (1.08mg/dl ; $p < 0.001$). Both dietary vitamin C intake and serum vitamin C levels showed a significant negative correlation with blood lead level ($p < 0.001$), which indicates that strategies of dietary management to promote the health of Korean lead workers should focus on promoting the vitamin C intakes of individuals. (*J Community Nutrition* 6(2) : 97~102, 2004)

KEY WORDS : serum vitamin C · blood lead · dietary vitamin C intake · lead workers.

Introduction

Regular medical surveillance of lead workers in Korea—mainly by annual health examinations and biological monitoring— has shown that the number of lead poisoning cases during the past two decades has decreased (Lee BK 1991). However, there is still considerable concern about the toxicological implications of occupational exposure to relatively high lead levels. Various ways of further reducing and also treating the effects of such exposure have been looked at intensively, including examination of nutritional influences (World Health Organization 1995 ; United Stastes Environmental Agency 1998). Previous studies have revealed that vitamin C is one of many nutritional factors that influences lead toxicity. One animal study showed that orally administered ascorbic acid had lead-chelating properties similar to those of parenterally administered EDTA, which is a standard treatment for lead poisoning (Goyer RA 1979). However, other trials involving a small number of human subjects have yielded inconclusive results (Holmes HN 1939 ; Sohler A 1997 ; Lauwerys R 1983 ; Calabrese EJ 1987 ; Dawson EB 1999). A population-based epidemiology study showed that high serum levels of vitamin C are associated with a decreased incidence of elevated blood lead levels, suggesting that vitamin C intake has public health implications for the control of lead toxicity (Simon JA 1999).

Recently, nutrition has become a critical issue in modulating the toxicity of environmental pollutants and therefore modulate health and disease outcome associated with chemical insults (Hennig B 2004). An understanding of the role nutrition plays in short- and long-term health may significantly minimize the risk of lead toxicity. There is a need to ascertain whether a modification of vitamin C

---

†**Corresponding author** : Hee-Seon Kim, Department of Food Science and Nutrition, Soonchunhyang University, 646 Eupnae-ri, Shinchang-myun, Asan-si, Choongnam 336-745, Korea
Tel : (041) 530-1263, Fax : (041) 530-1264
E-mail : hskim1@sch.ac.kr

nutritional status of Korean lead workers could be used as an efficient secondary preventive intervention against their high blood lead levels. Therefore, the purpose of this study was to estimate the nutritional status and to identify the relationships between dietary vitamin C intake, serum vitamin C level, and blood lead level in male Korean lead workers. The specific research purposes were 1) to measure the actual nutrient intake levels of Korean male lead workers, 2) to investigate the differences in blood lead levels and vitamin C intakes of lead workers and non-lead workers, and 3) to evaluate the associations between blood lead levels, serum vitamin C levels, and dietary vitamin C intakes. The ultimate aim of the study was to establish the dietary guidelines for workers with occupational lead ex-posure that would help prevent lead poisoning.

Materials and Methods

1. Subjects

Participation in the study was voluntary, and all participants provided written informed consent before setting the interview schedule.

One hundred thirty five male lead workers were recruited from two lead storage-battery factories. Among them, 118 workers, who had received mandatory special health examinations by the Institute of Industrial Medicine at Soonchunhyang University, and without evident medical problems, were considered eligible for the present study : they participated in two site-visit examinations during September 2000. One hundred control subjects without occupational lead exposure were recruited from among those who visited Soonchunhyang University Hospital at Chunan for a mandatory annual medical examination between September and November 2000. The study included only male subjects since there are more men than women in lead-handling industries (average, 87.2%) (Kim HS 2001). After health screening examination, 63 eligible male subjects were selected to participate in the study as the non-lead-exposed control. We excluded women and those who had been diagnosed with GI tract disease, hypertension, diabetes mellitus, liver or lung problems and those taking prescription drugs.

2. Data collection and analyses

All participants' heights and weights were measured for assessing body mass index (BMI). Dietary intakes were assessed with a 24-hr recall method by one-to-one interview with trained interviewers. Plastic food models, standard household measures, and natural-sized colored photographs were used as memory aids to obtain detailed descriptions of all foods and beverages consumed and to estimate food portions correctly. Food records were converted to nutrient intakes using a computerized nutrient analysis program (CAN-pro, Korean Nutrition Society 1998). Evaluation of nutrient intakes was made with reference to the recommended dietary allowances (RDAs) for the Korean population (The Korean Nutrition 2000).

Approximately 10ml of venous blood was collected and divided into two tubes : 4 ml blood in a vacutainer with EDTA for whole blood lead (PbB) ; and 6 ml blood in a vacutainer with SST® Gel & clot activator for serum vitamin C analysis. Serum vitamin C levels were analyzed using HPLC (TOSHO, Japan) according to modified versions of the methods of Lee et al. (Lee SS 1998) and Kim et al. (Kim CJ 1996). Briefly, 200μl of serum was mixed with 5% metaphosphoric acid using a vortex mixer, and centrifuged at 9,300 × g for 15 minutes. A 20-μl aliquot of the centrifuged extract was filtered and injected to HPLC. Blood lead levels were analyzed by the Zeeman background-corrected flameless atomic absorption method (graphite furnace) using a spectrometer (model Z-8100, Hitachi, Japan) at the Institute of Industrial Medicine, Soonchunhyang University, which is a certified reference laboratory for lead in Korea.

3. Statistical analysis

Data were analyzed by the SPSS (MS-Windows V10.0) program. Independent t-tests were conducted for general characteristics, nutrients intakes, blood lead levels, and serum vitamin C concentrations between lead workers and non-lead workers, and Pearson's correlations were used for comparing elevated blood lead levels with anthropometric, biochemical, and nutritional factors. Multiple regression models were used to examine the relation between vitamin C intake and serum vitamin C concentration and blood lead levels, whilst controlling for non-nutrient variables such as age, BMI, and occupational lead exposure which may have confounded the association between lead and vitamin C nutrition.

To minimize extraneous errors in estimating nutrient intake due to individual differences in total food intake, each nutrient intake was normalized relative to the total energy intake. The calorie-adjusted intakes of vitamin C and other nutrients for each individual were computed by taking the residual from the regression model in which total caloric intake was the independent variable and the observed intake of vitamin C or other nutrient was the dependent variable, plus a constant equal to the expected intake of vitamin C or other corresponding nutrients for the mean caloric intake of the study population. The regression models used to calculate energy-adjusted nutrient intakes were analyzed on a natural logarithmic scale to improve stability over the whole range of nutrient intakes levels (Willett WC 1990).

Results

The general, anthropometric, and biochemical characteristics, and smoking and alcohol-consumption habits of subjects are shown in Table 1. There were no differences observed in the mean age, height, weight, and BMI between non-lead and lead workers. Relative to lead workers, the mean blood lead level of non-lead workers was significantly lower (5.1 μg/dl, $p < 0.001$) and the serum vitamin C level was significantly higher (1.08mg/dl, $p < 0.001$). The mean blood lead level of lead workers was 30.9μg/dl, and the levels varied over a wide range (5.5–73.5μg/dl). The proportion of smokers was lower in lead workers, but the proportion of subjects who smoked more than 20cigarettes/day and more than 10years were both higher for lead workers than for non-lead workers (data not shown). The proportion of lead workers that consumed alcohol was lower than that for non-lead workers, but lead workers drank more frequently and consumed more alcohol than non-lead workers (data not shown).

Table 2 shows the energy-adjusted nutrient intakes of the subjects. Normalizing dietary nutrient intake to total energy intake values reduced the nutrient intakes of both lead and

Table 1. General, anthropometric, and biochemical characteristics of the subjects

Variable	Non-lead workers (n=63)	Lead workers (n=118)	t
Age (yrs)	40.8 ± 7.4 1)	38.3 ± 10.2	1.76
Occupation	Frequency (%)	Frequency (%)	
Lead factory	0(0)	118(100)	
Management	15(23.8)	0(0)	
Office work	14(22.2)	0(0)	
Industry work (not lead)	11(17.5)	0(0)	
Sales	6(9.5)	0(0)	
Agriculture	4(6.3)	0(0)	
Small shop owner	3(4.8)	0(0)	
Transportation service	2(3.2)	0(0)	
Unemployed	2(3.2)	0(0)	
Other	6(9.5)	0(0)	
Smokers (%)	64	59	
Alcohol drinkers (%)	84	74	
Height (cm)	1) 169.8 ± 5.0	169.5 ± 6.2	0.30
Weight (kg)	67.7 ± 9.3	65.7 ± 9.6	1.37
BMI (kg/m^2)	23.5 ± 2.9	22.9 ± 3.2	1.22
Blood lead (μg/dl)	5.1 ± 1.3	30.9 ± 15.2	−12.22***
Serum vitamin C (mg/dl)	1.08 ± 1.34	0.10 ± 0.33	13.45***

1) Mean ± SD, * : $p < 0.05$, ** : $p < 0.01$, *** : $p < 0.001$

Table 2. Energy-adjusted nutrient intakes of the subjects

Nutrient	Non-lead workers (n=63)		Lead workers (n=118)		t
	Intake	%RDA	Intake	%RDA	
Energy (kcal)	2234.0 ± 698.1 1)	91.0	2138.4 ± 612.39	86.6	0.953
Protein (g)	80.6 ± 13.1	115.2	73.4 ± 13.06	104.9	3.557***
Fat (g)	47.2 ± 14.5		47.2 ± 13.53		0.010
Carbohydrate (g)	309.5 ± 60.5		306.9 ± 54.07		0.295
Ca (mg)	573.3 ± 203.2	81.9	483.3 ± 161.03	69.0	3.263**
P (mg)	1200.7 ± 200.2	171.5	1118.1 ± 206.46	159.7	2.592**
Fe (mg)	14.6 ± 11.9	121.3	11.4 ± 6.48	94.6	2.341*
Vitamin A (μgRE)	769.1 ± 363.9	109.9	622.9 ± 554.12	89.0	1.887
Vitamin B_1 (mg)	1.3 ± 0.4	97.7	1.3 ± 0.44	104.5	−1.189
Vitamin B_2 (mg)	1.1 ± 0.3	75.9	1.1 ± 0.37	73.0	0.851
Vitamin C (mg)	129.3 ± 69.2	184.8	65.1 ± 35.05	93.0	8.294***
Niacin (mg)	17.7 ± 4.2	106.1	14.6 ± 3.80	87.6	5.158***

1) Mean ± SD, * : $p < 0.05$, ** : $p < 0.01$, *** : $p < 0.001$

non-lead workers. The overall nutrient intakes of lead workers were lower than those of non-lead workers. However, the intakes of most of the nutrients for both groups exceeded 75% of their corresponding RDA values, except for the calcium and vitamin B_2 intakes of lead workers. Intakes of protein, calcium, phosphorous, iron, vitamin C, and niacin of the lead workers were significantly lower than those of the non-lead workers ($p < 0.001$, $p < 0.01$, $p < 0.01$, $p < 0.05$, $p < 0.001$, and $p < 0.001$, respectively). In particular, the mean vitamin C intake of non-lead workers was twice that of lead workers.

Table 3 shows the unadjusted correlations between blood lead level and anthropometric measurements, serum vitamin C level, and energy-adjusted dietary vitamin C intake. Blood lead level was positively correlated with age and negatively correlated with serum vitamin C concentration and energy-adjusted dietary vitamin C intake ($p < 0.01$). The serum vitamin C concentration was positively correlated with energy-adjusted dietary vitamin C intake ($p < 0.01$).

Table 4 summarizes the results of multiple regression of blood lead levels against age, BMI, serum vitamin C level, and energy-adjusted dietary vitamin C intake. Since the age and BMI variables accounted for 7.9% (model 1) or 4.8% (model 2) of blood lead level variations by themselves (data not shown), the variables were added in the regression to control for variations in blood lead level attributable to general characteristics. Serum vitamin C level and dietary vitamin C intake account for an additional 31.6% and 40.0% of the blood lead level variation, respectively. The effect of serum vitamin C and dietary vitamin C intake on blood lead levels was statistically significant ($p < 0.001$). Since smoking and alcohol consumption could influence both serum vitamin C concentrations and blood lead levels, we also conducted regression with these factors controlled ; this did not affect the results (data not shown).

Table 3. Unadjusted correlations of age, BMI, blood lead level, serum vitamin C, and energy-adjusted dietary vitamin C intake of the subjects (n = 181)

Variable	Blood lead level	Age	BMI	Serum vit. C
Age	0.183*			
BMI	−0.101	0.108		
Serum vit. C	−0.532**	0.145	0.080	
Dietary vit. C	−0.400**	0.228**	0.079	0.416**

* : p<0.05, ** : p<0.01, *** : p<0.001

Table 4. Multiple regression on blood lead level by serum and dietary vitamin C of the subjects (n = 181)

Variable	R^2	β	F/t	p
Model 1	0.395		13.835	<0.001
Age		0.224	2.950	0.004
BMI		−0.104	−1.412	0.160
Serum vitamin C		−0.388	−4.834	<0.001
Model 2	0.448		10.635	<0.001
Age		0.295	4.678	<0.001
BMI		−0.053	−0.868	0.387
Dietary protein		−0.337	−2.787	0.006
Dietary calcium		−0.054	−0.437	0.663
Dietary iron		−0.104	−1.642	0.103
Dietary vitamin C		−0.312	−3.618	<0.001

Discussion

The mean serum vitamin C level of lead workers (0.10 mg/dl=5.7μmol/l) is seriously low according to the American or Canadian interpretive criteria levels (Gibson RS 1990 ; Sauberlich HE 1981) (note that the corresponding level for Koreans has not been defined, but are likely to be similar). Protracted low intakes of vitamin C (less than 20 mg/day) are known to rapidly reduce serum vitamin C levels to 0.20mg/dl (11.4μmol/l) or less (Jacob RA 1987). The dietary intake of vitamin C among lead workers was not low (at 93% of the Korean RDA, 65.9mg/day), but it was significantly lower than that of the non-lead worker group ($p < 0.001$). Moreover, the mean serum vitamin C concentration of non-lead workers was about 10 times higher than that of lead workers. This serum vitamin C concentration (1.08mg/dl) and dietary intake of 129.3mg/day might be relatively high, but can be considered to be normal for Korean men when compared to previously reported values (Jacob RA 1987 ; Kang MH 2001).

The results of the current cross-sectional study may have been influenced by misclassification or measurement errors. The one-day 24-hr recall method is certainly not perfect for measuring dietary vitamin C intake ; moreover, because blood lead is a biomarker of lead accumulation over a certain period of time, a 24-hr recall data may not provide correct information of dietary intake over the time of interest. Nevertheless, any measurement error generally biases the measured association toward the null, and hence is unlikely to have been fully responsible for our results. The chances of information bias are not high in this study, since most of the participants—both lead and non-lead workers—had been participating in the meal plans provided by their employers, making it unlikely that the subjects altered their diets. Also, the dietary nutrients intake was assessed by a highly trained interviewer via one-to-one interview whilst utilizing various tools to minimize any memory deficiencies.

Consistent with the study of Simon and Hudes (Simon JA 1999), our regression result confirmed that high serum levels of ascorbic acid are associated with a decreased incidence of elevated blood lead levels. Moreover, since vitamin C exhibits a stronger influence than all other vitamins on correlations between dietary intake and serum concentration (Bates CJ 1997), dietary intake also exhibited a significant negative association with blood lead levels. Inverse relations between dietary vitamin C intake and body lead accumulation have been consistently observed in both experimental (Flora SJ 1986) and intervention (Dawson EB 1999) studies. An epidemiologic study showed higher serum vitamin C levels are independently associated with a decreased prevalence of elevated blood lead levels (Simon JA 1999). Vitamin C is known not only to inhibit the uptake of lead from the gastrointestinal tract (Morton AP 1985), but also to increase the renal clearance of lead (Niazi S 1982). The inverse correlation between dietary vitamin C intake to blood lead level could provide an objective basis for health-policy decisions for industrial workers, especially for those involving lead handling. There is broad general agreement that primary prevention is the optimal approach to restriction of exposure to environmental lead (Committee on Lead in the Human Environment 1980). Whereas this broad consensus is widely embraced, the continuing problems of industrial exposure to lead are not yet resolved. Industrial lead exposure must continue to receive prioritized governmental and scientific support, and this must accompany any type of secondary prevention, such as dietary vitamin C management aimed at reducing the adverse effects of lead exposure.

References

Bates CJ, Thurnham DI (1997) : Biochemical markers of nutrient intake. In : Margetts BM, Nelson M, editors. Design Concepts in Nutritional Epidemiology. pp.209-211, Oxford University Press, New York

Calabrese EJ, Stoddard A, Leonard DA, Dinardi SR (1987) : The effects of vitamin C supplementation on blood and hair levels of cadmium, lead, and mercury. *Ann N Y Acad Sci* 498 : 347-343

Committee on Lead in the Human Environment (1980) : Lead in Human Environment. Washington DC : National Academy of Science

Dawson EB, Evans DR, Harris WA, Teter MC, McGanity WJ (1999) : The effect of ascorbic acid supplementation on the blood lead levels of smokers. *J Am Coll Nutr* 18 : 166-170

Flora SJ, Tandon SK (1986) : Preventive and theraputic effects of thiamins, ascorbic acid and their combianation in lead intoxication. *Acta Pharmacol Toxicol* 58 : 374-378

Gibson RS (1990) : Assessment of iron status. In : Gibson RS, editor. Principles of Nutrition Assessment. pp.349-376, Oxford University Press, New York

Goyer RA, Cherian MG (1979) : Ascorbic acid and EDTA treatment of lead toxicity in rats. *Life Sci* 24 : 433-438

Hennig B, Toborek M, Bachas LG, Suk WA (2004) : Emerging issues : nutritional awareness in environmental toxicology. *J Nutr Biochem* 15 : 194-195

Holmes HN, Campbell K, Amberg EJ (1939) : The effect of vitamin C on lead poisoning. *J Lab Clin Med* 24 : 1119-1127

Jacob RA, Skala JH, Omaye ST (1987) : Biochemical indices of human vitamin C status. *Am J Clin Nutr* 46 : 818-826

Kang MH, Yun JS (2001) : The effects of exercise on the vitamin C and E intakes and their plasma levels of vitamin C, alpha-tocopherol and gamma-tocopherol in young meale adults. *Korean J of Nutr* 34 : 306-312

Kim CJ, Park JS, Kim SY, OH DK (1996) : Varietal differences among soybean sprouts during germination and maturation. *Korean Soybean Digest* 13 : 55-61

Kim HS, Song OY, Lee SS, Hwangbo Y, Ahn KD, Lee BK (2001) : Assessment of nutritional status by estimation of nutrients and food intakes of the lead workers in the Republic of Korea. *Nutr Sci* 4 : 91-97

Lauwerys R, Roels H, Buchet JP, Bernard AA, Verhoeven L, Konings J (1983) : The influence of orally-administered vitamin C or zinc on the absorption of and the biological response to lead. *J Occup Med* 25 : 668-678

Lee BK (1991) : Lead poisoning in Korea. *Korean J Occup Health* 30 : 1-9

Lee SS, Choi IS, Lee KW, Oh SH (1998) : Effect of antioxidant vitamin supplementation on blood composition in smoking college men. *Korean J Nutr* 31 : 289-296

Morton AP, Partridge S, Blair JA (1985) : The intestinal uptake of lead. *Chem Br* 15 : 923-927

Niazi S, Lim J, bederka JP (1982) : Effect of ascorbic acid on the renal excretion of lead in rats. *J Pharm Sci* 71 : 1189-1190

Sauberlich HE (1981) : Ascorbic acid (vitamin C). In : Labbe RF, editor. Symposium on Laboratory assessment of Nutritional Status. *Clinics in Laboratory Medicine* 1 : 673-684

Simon JA, Hudes ES (1999) : Relationship of ascorbic acid to blood lead levels. *JAMA* 281 : 2289-2293

Sohler A, Kruesi M, Pfeiffer CC (1977) : Blood lead levels in psychiatric outpatients reduced by zinc and vitamin C. *J Orthomolecular Psych* 6 : 272-276

The Korean Nutrition Society (2000) : Recommended Dietary Allowances for Korean, 7th revision, KNS, Seoul

United Stastes Environmental Protection Agency (1998) : Lead in your home : a parent's reference guide. Washington DC : US Government Office

Willett WC (1990) : Implications of total energy intake for epidemiologic analyses. In : Willett WC, editor. Nutritional Epidemiology. pp.245-271, Oxford University Press, New York

World Health Organization. Inorganic lead (1995) : Environmental Health Criteria 165. WHO, Geneva