Boron Workers in China

Exploring Work and Lifestyle Factors Related to Boron Exposure

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RESEARCH ABSTRACT

This article describes the lifestyle patterns of boron mining and processing workers ($N = 936$) and a comparison group ($N = 251$) in northeast China, and explores relationships between boron exposure and reproductive health. An English version of an interview guide addressing areas of work and lifestyle relevant to boron exposure and metabolism was developed by an occupational health research team, translated to Chinese, and translated back, for clarity. Modifications incorporated suggestions from a local community advisory board and boron industry workers; the translation–back translation process was reapplied, and cultural and semantic equivalence was attained. Results from the interviews showed more than 64% of workers and comparison group participants smoked tobacco and more than 92% reported exposure to environmental tobacco smoke. Boron workers and the comparison group varied in their food intake and alcohol consumption, but not in their smoking habits. Thirty-four percent of boron workers reported eating in the contaminated work area. Nearly all boron workers (99%) showered or bathed after work, although approximately 10% redressed in their contaminated clothes. Reproductive health outcomes were explored, including delayed pregnancy, multiple births, spontaneous miscarriages, induced abortions, stillbirths, and an unusual ratio of male to female offspring. Implications for occupational health nurses and recommendations for future research are provided.

With increasing globalization, occupational and environmental health nurses have actively engaged in promoting international health and safety in the workplace. To advance education, practice, and research in international occupational and environmental health nursing, it is first necessary to increase the awareness of safety and health issues in other countries (Hong, 2003). To this end, the authors describe work patterns and lifestyles of workers in the boron mining and processing industry in northeast China and explore relationships between boron exposure and reproductive health.

Moorman et al. (2000), in a special panel review of 43 National Toxicology Program reproductive toxicants, ranked boric acid as one of the four highest priority substances for human field study. This ranking was based on the strength of animal data suggesting a reproductive hazard at a relatively low exposure level, estimated worker populations at risk (> 100,000), and lack of adequate human data on reproductive toxicity. Although animal studies show effects of boric acid on male reproduction at comparatively low doses (145 mg/kg/d in the rat), only three human studies had been published on reproductive effects of occupational boron exposure at the time of the special panel review. One study found testicular atrophy and sterility following exposure (Tarasenko, Kasparov, & Strongina, 1972). Whorton, Haas, and Trent (1994), using questionnaires and standardized birth ratios, showed no effect of boron on fertility, although more female than male offspring were noted. Tuccar, Elhan, Yavus, and Sayli (1998) and Sayli (1998) found no adverse effects on either male or female fertility or development in studies conducted in Turkey; but, compared with national

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Applying Research to Practice

Occupational health nurses are in a strategic position to assess workplace and environmental hazards that may affect the reproductive health of male workers. Results of this study have implications for incorporation of environmental and sociocultural elements into nurses' assessment that may not have been considered previously. This study also highlights the importance of potential confounders of reproductive health such as tobacco and alcohol. Lifestyle descriptions can identify at-risk worker profiles (e.g., alcohol consumption that may potentiate the effect of workplace exposures). Furthermore, in this era of globalization and immigration, occupational health nurses may encounter workers and families from different cultures. Hence, occupational health nurses need to be aware of culturally diverse individual habits and home and other environments. Occupational health nurses are in a pivotal position to perform comprehensive assessments of workers and are encouraged to participate in reproductive health research regarding boron or other industrial materials that furnish both occupational and general sources of exposure.

norms, less than the expected number of males were born to women living in regions with high boron exposures. These human studies have been criticized for their use of standardized birth ratios and historical exposure data (Whorton et al., 1994), or sampling techniques and lack of exposure measurements (Sayli, 1998; Tuccar et al., 1998).

When learning about the effects of occupational boron exposure in humans, it is also important to know the sources of non-occupational exposure. Because boron is present in foods and household cleaning agents and is absorbed through the gastrointestinal and respiratory tracts, sources of exposure extend beyond the workplace. Occupational health nurses are in an excellent position to identify factors that affect boron exposure in workplace, home, and social environments. Insight can be gained into the workers' lifestyles through self-report, during interview sessions. Protective behaviors in the workplace as well as individual habits, eating behaviors, and exposures to other materials in the environment can be addressed. Knowledge of such behavior aids in a comprehensive understanding of exposure that may contribute to workers' adverse reproductive health.

BACKGROUND

Boron is a trace element found throughout nature. Boronic compounds are commonly found in water, vitamin supplements, some foods, medicines, fertilizers, and household detergents. Although boron has not been designated as an essential nutrient for humans, several research studies suggest that this is probably the case (e.g., Meacham & Hunt, 1998; Nielsen, 1996). On the other hand, high concentrations of boron are toxic to animals, causing poor appetite, weight loss, vomiting, diarrhea, dermatitis, anemia, lethargy, and seizures (Linder, Strader, & Rehnberg, 1990). Insufficient studies have been conducted to verify symptoms in humans.

Boron is absorbed through the gastrointestinal (Murray, 1998) and respiratory (LaDou, 1997) tracts. Once absorbed, boron is rapidly distributed throughout the body as borates or boric acid, reacting with certain biological ligands (e.g., alcohols and sugars) to form boroesters (Hunt, 1998). Boron influences several enzymes (Hunt, 1998), and the enzyme-stabilizing ability of simple borates has led to their use in laundry detergents (Woods, 1994).

Boron is excreted through the kidneys, unchanged, with a half-life of 21 to 24 hours (Culver et al., 1994; Murray, 1998). Studies confirm that boron excretion in urine is 84% to 90% of boron intake (Hunt, Herbel, & Nielsen, 1997); thus, boron does not accumulate appreciably in the human body except slightly in bone, hair, and teeth (Culver et al., 1994; Hunt et al., 1997; Murray, 1998; Sutherland, Woodhouse, Strong, & King, 1999).

The current descriptive study is based on interview data from a larger study on the relationship between workplace exposure to boron-containing compounds and adverse male reproductive effects. The goals of this report are to describe the lifestyle patterns of boron workers and a comparison group and to explore relationships between boron exposure and reproductive health. Reproductive health is represented by self-report of delays in pregnancy, pregnancy outcomes, total number of children, and gender of children. Specific questions addressed are:

1. What is the pattern of food and water consumption of boron workers and a comparison group?
2. What are the occupational personal protective methods, if any, used by boron workers?
3. What is the pattern of exposure to potential confounders of reproductive health such as tobacco and alcohol?
4. What is the relationship between boron exposure and reproductive health?

METHOD

Design

The current study is a cross-sectional, descriptive design based on interviews with participants who have occupational exposure to boron and a comparison group selected from an environment without significant exposure to boron.

Setting

The study was approved by the University of California, Los Angeles, Institutional Review Board in the United States for the protection of research participants, and

by an appropriate counterpart at the China National Environmental Monitoring Center in Beijing. The settings for the exposed and comparison groups were based on initial background soil and water characteristics. Individuals in the boron-exposed group were from environments with higher boron concentration in water sources and foods than the comparison group. Samples were taken upstream of the river for area 1, and downstream of the river for area 2 (Table 1).

The level of industrial exposure for boron workers from air dust, calculated assuming inhaled air volume of 15 m^3 for an 8-hour workday, ranged from 0.06 to 51.07 mg. The workplace boron exposure for the comparison group was 0.005 to 0.016 mg under the same assumptions. Depending on the composition of borates in the dust, the National Institute for Occupational Safety and Health (1997) recommends exposure limits of 1 to 5 mg/m^3 for an 8-hour, time-weighted average.

Data for the exposure group were obtained by interviewing workers at boron mines and processing plants located in Kuandian City, Liaoning Province, People's Republic of China. These interviews were completed through collaboration with local officials of the Dandong Environmental Monitoring Center under the direction of the General Engineer of the China National Environmental Monitoring Center in Beijing. A total of five boron mines and processing plants, employing approximately 3,500 male workers, were selected for the study. These sites were chosen based on the number of employees, availability of an industrial hygienist on site willing to collaborate, and geographical location. The comparison group was selected from another town, Tiantuia Gu, 30 miles away from the boron mines and processing plants, with a known low background of environmental boron (Table 1).

Table 1

Environmental Boron Exposure for the Two Groups

Substance Tested	*Boron Workers Mean*	*Comparison Group Mean*
Surface water		
Area 1	2.6 mg/L	0.005 mg/L
Area 2	3.8 mg/L	0.67 mg/L
Well water		
Area 1	1.2 mg/L	0.002 mg/L
Area 2	25.1 mg/L	0.67 mg/L
Soil		
Area 1	133 mg/kg	38.8 mg/kg
Area 2	1,195 mg/kg	82.4 mg/kg
Legumes	40.7 mg/kg	24.9 mg/kg
Potatoes	12.4 mg/kg	6.0 mg/kg
Soybeans	34.0 mg/kg	43.0 mg/kg

Sample

Participant inclusion criteria for the boron exposure group included employed in mines or processing plants, willing to participate in an interview by a local researcher for information on diet, work history, fertility history, and health history, and willing to have samples of food and fluid intake for a full 24-hour period taken by the researchers. The inclusion criteria for the comparison group included residence in Tiantuia Gu, employed but not in the boron industry, and willing to participate in interviews and food and water sampling. The comparison group's occupations were office workers, taxi drivers, coal mine workers, train station workers, post office workers, teachers, police station workers, and farmers. A final sample of 936 male boron workers and 251 comparison men were interviewed for this preliminary study on lifestyles. Table 2 lists the sociodemographics of the two groups.

Instruments

Prior to the development of an interview guide, areas of lifestyle relevant to boron exposure and metabolism were identified, including sociodemographics, smoking, alcohol use, food and beverage consumption, work exposure to boron, and general and reproductive health.

Specific questions were then developed according to the relevant concepts, with input from all members of the research team in the United States and China and consultants from the boron industry. Issues of item relevance to concepts, comprehensiveness of items to measure identified concepts, understandability, and cultural appropriateness were addressed. These questions were communicated to research collaborators in China, and then modified based on their comments.

The resulting questionnaire draft was again translated to Chinese and presented to an advisory board of local community leaders in China. The community leaders and workers in the boron industry gave further suggestions, which were then incorporated. This modified version was then translated to English, and back to Chinese, for comparison by bilingual members of the team. The tool was field tested in China and areas of disagreement were discussed until a consensus could be reached for conceptual, cultural, and semantic equivalence. The final version was used for the current study.

Procedure

The U.S. investigators trained interviewers in China. The U.S. team developed a step-by-step procedure, including principles of interviewing, for the local research team. Prior to leaving the United States for China, the team prepared a written manual in English and Chinese for interviewers to use during the training session. They were to keep the manual for reviewing at any time during the data collection period.

In administering the interview, interviewers were trained to avoid biasing responses, help the participants

Table 2

Sociodemographics of the Two Groups

Characteristic	Boron Workers (n = 936)	Comparison Group (n = 251)
Age, year		
Mean	36.44	37.84
SD	8.41	7.40
Education—highest level completed		
Elementary	210 (22.43%)	51 (20.32%)
Middle	513 (54.81%)	97 (38.65%)
High	190 (20.30%)	41 (16.33%)
College	23 (2.46%)	62 (24.70%)
Race		
Hanzu	520 (55.56%)	82 (32.67%)
Manzu	410 (43.80%)	166 (66.13%)
Chaoxianzu	2 (0.21%)	3 (1.20%)
Other	4 (0.43%)	0 (0.00%)
Marital status		
Never married	90 (9.61%)	5 (1.99%)
Widowed or divorced	17 (1.82%)	6 (2.39%)
Married	829 (88.57%)	240 (95.62%)

feel relaxed during the interview process, and record responses completely and accurately. In addition, they were trained according to approved procedure for the protection of human participants. They were proficient in explaining the rights and requirements of participants involved in the current research, and in obtaining voluntary written consent from the potential participants.

Data Analysis

Trained research assistants (four doctoral students and four employees from the Dandong Environmental Monitoring Station) conducted the interviews and recorded the participants' answers in the written questionnaires. Two separate research team members recorded 5% of all the interviews to determine the interview error rate. The data were then coded according to a predetermined coding plan. The data were available for analysis in China as well as the United States electronically.

The data analysis for this article was generated using SAS software (version 8, SAS Institute Inc., Cary, NC). Where appropriate, nonparametric Wilcoxon two-sample or Kruskal–Wallis tests were performed for food consumption, number of days wearing the same clothes, alcohol and other beverage consumption, number of live births, and number of pregnancies fathered altogether. Chi-square or Fisher's exact tests were used for categorical variables such as tobacco exposure, use of alcohol, and reproductive health outcomes, including delays in pregnancy.

RESULTS

Patterns of Food Consumption (Table 3)

Based on the background assessment of food intake conducted by the Chinese research team, high levels of boron were present in vegetables grown in Liaoning Province (e.g., legumes, corn, and potatoes) but not in foreign-grown vegetables (e.g., rice). A closer examination of foods consumed showed that participants with a higher level of education, regardless of group, consumed more meat, fish, and fruit.

Occupational Personal Protective Methods

An examination of the occupational personal protective equipment used by boron workers indicated that the type most commonly used provided dermal protection: long pants (97.2%), long sleeve shirts (76.7%), protective material for the hands (56.9%), and head gear (56.5%). The use of respiratory protection was variable. The most commonly used type was a half-face air-purifying respirator that fit over the nose and mouth with a removable filter on each side, for protection from airborne particles. However, the use of respirators was not always accompanied by frequent changes in filters. In some cases filters were missing.

Bath or shower facilities were generally provided at the workplace for workers exposed to dust. Ninety-nine percent of boron workers took showers or baths after work; the frequency ranged from 1 to 5 times per week with the modal response (34.8%) being 2 per week. Approximately 90% of the boron workers reported changing clothes after the work shift. The mean number of days that boron workers wore the same clothes at work without washing was 17 (SD = 40 days; median = 7 days).

Because ingestion is a major source of boron exposure, workplace eating was examined. The researchers found that 64% of boron workers ate at the worksite, with as much as one-third eating directly in the work area.

Exposure to Lifestyle Factors

An important aspect of occupational health is the examination of lifestyle factors that may interact with workplace exposures to affect health, such as exposure to tobacco smoke and consumption of alcohol. Both smoking and alcohol intake have been shown to affect male fertility through adverse effects on semen quality (Robbins et al., 2005; Vine, Margolin, Morrison, & Hulka, 1994).

Differences were not statistically significant between the boron exposed and comparison groups regarding current (64% boron workers and 69% comparison group) or past (8% boron workers and 5% comparison group)

Table 3

Type and Amount of Food Consumed by the Two Groups

Food	Boron Workers (n = 936) Mean (jin/mo)*	(SD)	Comparison Group (n = 251) Mean (jin/mo)	(SD)	p†
Rice	14.12	(6.99)	13.93	(6.90)	.80
Wheat	6.87	(5.55)	6.15	(5.09)	.05
Corn	2.24	(3.57)	3.95	(5.13)	< .0001
Meat	4.20	(3.62)	4.35	(4.66)	.25
Soybeans	6.44	(5.62)	8.91	(7.20)	< .0001
Eggs	4.89	(4.15)	4.12	(3.20)	.01
Fish	2.65	(2.55)	3.01	(2.71)	.03
Cucumbers	6.29	(6.75)	9.36	(9.97)	< .0001
Peas	9.60	(8.00)	12.46	(9.84)	< .0001
Eggplants	4.58	(4.63)	5.75	(5.25)	< .0001
Potatoes	7.10	(6.89)	9.10	(8.04)	< .0001
Fruit	11.43	(11.85)	12.02	(10.94)	.20

**1 jin = 17.637 ounces.*

†Nonparametric Wilcoxon two-sample test was used to calculate p *values due to the skewness of the data.*

tobacco use. Although the large sample size resulted in statistically significant differences in exposure to secondhand or environmental smoke, approximately 97% of the boron workers and 93% of the comparison group reported being in the vicinity of individuals who smoked (Table 4). Hence, these differences may have little or no clinical significance regarding long-term effects, as both groups are highly exposed.

Comparison group members consumed more white and red wine than boron workers, whereas boron workers drank significantly more well and tap water (Table 5). Well or tap water obtained close to boron ore beds is likely to contain higher levels of boron. Boron workers drank more tap water than comparison group members regardless of education level or race. Manzu individuals in the boron worker group also drank more well water than comparison group members.

The comparison group consumed more white wine, especially individuals whose highest level of education completed was high school (comparison group, 12.2 li-

Table 4

Tobacco Exposure for the Two Groups (*N* = 1,187)

Group	Current Tobacco Use	Past Tobacco Use	Never Used Tobacco	p*	Exposure to Secondhand Smoke	p†
Boron workers (*n* = 936)	64.21%	8.33%	27.46%	.18	96.79%	.005
Comparison group (*n* = 251)	68.92%	5.18%	25.90%		92.83%	

**p value for two groups (boron vs. comparison) across three categories (current tobacco use, past tobacco use, and never used tobacco) (chi-square test).*

†p value for two groups (boron vs. comparison) for exposure to secondhand smoke (chi-square test).

Table 5

Type of Beverages Consumed by the Two Groups ($N = 1,187$)

Group	Drinking Alcohol	Beer		White Wine		Red Wine		Tea		Tap Water		Well Water	
		Mean (L/wk)	(SD)	Mean (liang/wk)*	(SD)	Mean (liang/wk)	(SD)	Mean (L/d)	(SD)	Mean (L/d)	(SD)	Mean (L/d)	(SD)
Boron workers ($n = 936$)	53.31%	1.40	(2.57)	7.36	(15.08)	0.00	(0.10)	0.07	(0.42)	0.16	(0.49)	1.18	(1.13)
Comparison group ($n = 251$)	56.18%	2.20	(4.66)	11.14	(19.87)	0.65	(9.36)	0.06	(0.24)	0.02	(0.17)	1.00	(1.44)
p	.42	.41		.0003		.01		.08		< .001		.003	

*1 liang = 50 cc.

ang/wk; boron group, 5.75 liang/wk; $p = .02$; 1 liang = 50 cc). White wine in China has a high alcohol content, as much as 65% (vol/vol), compared with red wine (12% to 15%) and beer (3% to 4%). High school graduates in the comparison group also drank significantly more red wine. Regarding beer consumption, the boron workers were not statistically significantly different from the comparison group.

Overall, a higher percentage of individuals who were widowed or divorced (65.52%) consumed alcohol than those currently married (47.34%) or never married (31.58%). A closer examination of the three marital status groups showed that the differences were related to white wine intake.

Reproductive Health

Reproductive health outcomes included delay in pregnancy, multiple births, spontaneous miscarriages, induced abortions, stillbirths, and tubal or ectopic pregnancies (Table 6). On average, boron workers fathered nearly 2.0 pregnancies compared with 2.1 pregnancies for individuals in the comparison group ($p = .06$). Of the self-reported pregnancies fathered by boron workers, an average of 1.3 resulted in live births compared with an average of 1.4 for individuals in the comparison group ($p = .03$). A significant difference existed between groups in delay in pregnancy, defined as the inability to conceive within 1 year of desiring a child, with boron workers experiencing greater delays. However, in logistic regression models adjusting for age, education, race, tobacco, alcohol, and soybean consumption, the difference was no longer statistically significant ($p = .11$), with an odds ratio of 1.7 for boron workers versus comparison group members (95% confidence interval, 0.09 to 3.5).

In logistic regression models controlling for alcohol, smoking, education, and race, only education (less than high school) remained significant for greater delays ($p = .05$). Although not statistically significant, boron workers showed greater delays ($p = .06$). No differences between groups were observed in relation to the number of multiple births or spontaneous abortions.

Men with higher education in the boron group versus the comparison group were more likely to have wives who had induced abortions ($p = .015$). Couples in which men reported drinking alcohol were more likely to have had induced abortions ($p = .03$).

Wives of men in the boron group gave birth to 52.45% male offspring, whereas the wives of men in the comparison group gave birth to 54.35% male offspring.

DISCUSSION

Although boron may be an essential nutrient, the study of boron exposure in the workplace is challenging. Very low or very high doses could have adverse health effects, whereas moderate doses may be beneficial (Calabrese & Baldwin, 2003). Boron workplace exposure is not comparable to other workplace exposures because it could be exacerbated by additional environmental sources of boron, such as food and water. For example, results indicated that legumes and potatoes grown in areas of bo-

Table 6

Reproductive Health of the Two Groups* (*N* = 1,087)

Variable	*Boron Workers (n = 843)*	*Comparison Group (n = 244)*	p
Delay in pregnancy†	78 (9.42%; total = 828)	11 (4.62%; total = 238)	.018†
Multiple births	6 (0.71%)	3 (1.23%)	.428
Spontaneous miscarriage	65 (7.71%)	12 (4.92%)	.134
Induced abortion	332 (39.38%)	115 (47.13%)	.030
Stillbirth	9 (1.07%)	5 (2.05%)	.329
Tubal or ectopic pregnancy	3 (0.36%)	0 (0%)	> .999
More boys than girls‡	387 (55.52%; total = 697)	117 (60.31%; total = 194)	.234
Mean no. of pregnancies fathered altogether (*SD*)	1.98 (1.08)	2.11 (1.10)	.064
Mean total no. of live births (*SD*)	1.26 (0.61)	1.35 (0.65)	.028

**Males currently married, widowed, or divorced.*
†Based on 828 of the 843 boron workers and 238 of the 244 comparison group members who had been married for at least 1 year at the time of interview and answered "yes" to "trying for a child without success for more than a year." p = .11 after adjusting for age, educational level, race, smoking, alcohol use, and soybean intake.
‡Participants with equal numbers of boys and girls were excluded.

ron mining and processing were significantly higher in boron content than those in other areas. Boron workers could obtain significant exposure through a combination of work and diet.

The interviews indicated the most common method for workplace protection by boron workers was wearing long pants to prevent dermal exposure. The most common respiratory protection was a half-face air-purifying respirator, which was not frequently seen during the investigators' initial site visits to selected mines and factories. Furthermore, the investigators noticed filters missing from some of the respirators. During the course of the study, however, researchers noticed an increase in the display and use of respiratory protection.

Showers, provided by employers for use after work, were widely used by boron workers. Variation in the number of showers per week may have been related to the workers' perceived amount of accumulated dust exposure. Alternatively, frequency of showering may have been a personal practice, or a reflection of the company's provision of shower facilities. If the plant provided clean clothing, workers were more likely to change clothes.

More than 64% of boron workers and comparison group members reported currently smoking and 90% of both groups reported exposure to environmental tobacco smoke. Recent research unequivocally supports the adverse effects of environmental tobacco smoke (Centers for Disease Control and Prevention, 2006). In the United States, approximately 3,000 lung cancer deaths and 35,000 coronary heart disease deaths each year are related to smoking. Increasingly more locations in the United States are prohibiting smoking. Government agencies have joined professional and voluntary organizations to advance comprehensive programs that discourage young people from initiating a smoking habit, and attempt to eliminate exposure to secondhand smoke (CDC, 2005).

The number of smokers in China is currently higher than in the United States. According to a report from the World Health Organization (WHO) (2002), more than 300 million Chinese smoke—a number greater than the entire U.S. population. Smoking currently contributes to four of the five leading causes of death in China. Chinese consume an estimated 1.7 trillion cigarettes per year or 3 million cigarettes every minute, and secondhand smoke exposure remains a common preventable public hazard (WHO, 2002). The results in the current study, where 93% to 97% reported exposure to secondhand smoke, are consistent with WHO findings. The reduction of smoking is an issue ripe for public health intervention in China. Occupational health nurses are in an excellent position to adapt effective programs for smoking reduction in workplaces in China.

Alcohol consumption was found to be higher in the comparison group and, in particular, in those individuals whose highest level of education was elementary or high school. These findings have important implications for occupational health nurses in determining the reasons for high levels of consumption (e.g., social or stress-related), and in finding possible alternative solutions. Results also showed that individuals who were widowed or divorced consumed more alcohol than those who were currently

married. However, this finding is inconclusive, based on the small sample size.

Differences between the boron worker and comparison groups were seen when the average number of live births and delays in pregnancy were compared. The current study showed that even when alcohol, smoking, education, and race were controlled, boron workers experienced a greater likelihood of delays in pregnancy, although this finding was not statistically significant. Education was significant in both delays in pregnancy and induced abortions. The researchers were unable to determine whether educational differences were related to personal preferences, variation in income, or other factors. More extensive studies may yield the underlying reasons for these results. Regarding male-to-female birth ratios, a lower percentage of males were born to boron workers and their spouses than the comparison group, although this difference did not reach statistical significance.

Differences in observed versus expected male-to-female birth ratios, for offspring of boron workers, have been reported previously in California, and for men living in areas of relatively high environmental boron in Turkey (Sayli, 1998; Whorton et al., 1994). In a follow-up study, Sayli (2003) did not replicate the 1998 finding of a slightly lower percentage of male births to boron-exposed couples in Turkey, but reported a male-to-female birth ratio of 1.00 and a ratio of less than 1.05 for Turkey overall. In animal toxicology studies, delayed release of sperm into the lumen of the seminiferous tubule and retention of residual cytoplasm in maturing sperm cells are the initial effects of boron toxicity (Chapin & Ku, 1994; Ku, Chapin, Wine, & Gladen, 1993), but to date, none of these animal studies have published changes in sex ratios. It may be that variations in expected sex ratios were seen but not reported, or that humans' susceptibility in relation to boron toxicology differs from that of animals. However, data from the current study fit with a mechanistic model of epigenetic effects during the process of meiotic sex-chromosome pairing and inactivation that affects subsequent segregation of sex chromosomes, or post-meiotic gene reactivation patterns that may give selective advantage to X-bearing sperm (Handel & Hunt, 1992). Further studies are planned to discern the mechanism related to changed sex ratios.

If expected proportions are close to 50:50, a study group of approximately 1,700 offspring from boron-exposed men and an equal number from unexposed men would be required to verify statistically significant differences between the groups. An alternative way to view the data is to compare trends in male-to-female birth ratios in the study group, the comparison group, and surrounding communities.

Numerous factors may have contributed to high male-to-female birth ratios in China. A one-child per family policy was instituted in the 1970s. Although this policy may have been more relaxed in rural areas because of the need for labor, its effect is pronounced. The preponderance of boys is a result of cultural and parental preference in China.

LIMITATIONS

Limitations of this study are recognized. First, self-report data reflect subjective perceptions of the participants. The researchers have, however, taken precautions to ascertain validity of the instrument throughout its development, pre-testing, and revisions, in collaboration with the local population. Intensive interviewer training was conducted to insure "true" responses, without influence from the interviewers. In the process of data collection, means were instituted to ensure inter-rater reliability among interviewers and a low interviewer error rate of less than 0.8% was found. Because the sample is derived from a defined population, the results may be generalizable only to similar groups.

Although the researchers had a sample size of more than a thousand participants, some of the reproductive outcomes were rare occurrences (e.g., stillbirths). This limitation is common in studies of rare occurrences; creative approaches are needed for ways in which this limitation can be addressed in the future.

However, this study is one of the first to examine and compare the lifestyles and work habits of workers in boron mines and processing factories in China with those of a group without significant exposure to environmental boron. The information gained provides occupational health nurses with some insight into the lives of boron workers and their routes of exposure both on and off the job. Occupational health nurses may include factors related to environmental exposure in occupational health assessments. This information, in the case of boron workers, may contribute to future examination of the effect of boron on the reproductive systems of men.

This study has identified important areas for further investigation. More studies need to explore the finding of a lower than expected male-to-female birth ratio among boron workers compared with regional and national norms. This unexpected ratio should be investigated in relationship to boron workers' level of exposure, confounding variables of tobacco and alcohol, and other indicators of male reproductive health. Researchers may discover whether it is necessary to provide suggestions for worker protection related to boron and interventions related to lifestyle that would improve workers' health.

IMPLICATIONS FOR OCCUPATIONAL HEALTH NURSES

The evidence in this research emphasizes the importance of environmental sources and lifestyle factors that may influence workers' health. Lifestyle and cultural practices can work synergistically with workplace factors to place workers' health at risk. With increasing travel, immigration, and globalization, occupational health nurses must be alert to diverse lifestyles and sources of exposure to potentially harmful products. For workplace exposures such as boron, which may have a variety of environmental sources, a thorough sociocultural, lifestyle, and work-environment assessment is critical in determining adverse effects to the health of workers. Occupational health nurses have challenges and opportunities in performing comprehensive assessments to identify elements

in workers' daily lives that may affect their health. Ultimately, through prevention and workplace protection, they can improve health outcomes overall.

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