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Prevention of Lead Poisoning in Construction Workers: A New Public Health Approach

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Background. *In 1990, Yale University, the Connecticut Departments of Health Services and of Transportation, the Connecticut Construction Industries Association, and the state's construction trade unions created the Connecticut Road Industry Surveillance Project (CRISP).*
Methods. *Data from 90 bridge projects from 1991 to 1995 and approximately 2,000 workers were evaluated. The distribution of peak lead concentrations in the blood for CRISP workers classified into five groups were compared to that from workers outside of Connecticut.*
Results. *This demonstration project was instrumental in lowering bridge worker blood lead levels. After 1992, only the painting contract employees experienced peak blood lead levels with ≤2% exceeding 50 μg/dl. Compared to similar workers in other states, Connecticut workers had significantly lower peak blood lead levels.*
Conclusions. *Two thousand workers and over 120 contractors benefited directly from CRISP. Two key features of the CRISP model differed from the 1993 OSHA standard: a contract-specified lead health protection program and a centralized system of medical monitoring. These differences may account for the improved protection observed between the CRISP and non-Connecticut cohorts.* Am. J. Ind. Med. 39:243–253, 2001.

KEY WORDS: prevention programs; lead exposure; construction industry; OSHA lead standard

INTRODUCTION

In the United States there are an estimated 90,000 bridges with lead-containing paint on steel structures [OSHA, 1993]. In general, bridge maintenance work that disturbs lead paint entails torch cutting, grinding steel components, and removing and replacing paint. Workers involved in bridge repair have been among the commonly seen occupational groups with severely elevated blood lead levels. [O'Donnell, 1997; Reynolds et al., 1999]. This is problematic because chronic overexposure can result in severe damage to blood-forming, nervous, urinary and reproductive systems, and accumulation in bone tissue resulting in lead releases back into the bloodstream for many years [ATSDR, 1993; Barry, 1975; O'Flaherty, 1986; Hodgkins et al., 1991]. Severe health effects such as peripheral neuropathy and kidney damage above a blood lead level of 40 μg/dl and other renal effects such as decreased vitamin D metabolite levels at 30 μg/dl have been observed among workers who are chronically exposed to

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lead [Kim et al., 1996]. A positive association between blood pressure and lead in blood has been observed in men with levels as low as 7 μg/dl with no evidence of a threshold [Schwartz, 1988].

There are few descriptions of comprehensive strategies for controlling lead poisoning in the workplace [Hipkins et al., 1998; Baser, 1992; Lusk and Salazar, 1995; Papanak et al., 1992]. Although regulations exist and strategies have been proposed, lead poisoning continues to occur. This is particularly true among bridge construction workers involved in the burning and removal of lead paint on bridge surfaces. During an aggressive program to repair Connecticut's bridge infrastructure in the early 1990s, a new approach to prevent lead poisoning in construction workers was established called the Connecticut Road Industry Surveillance Project (CRISP). CRISP was a National Institute for Occupational Safety and Health (NIOSH)-funded demonstration project designed to monitor and prevent lead poisoning during bridge repair projects through a coordinated network of state agencies and local labor unions. At the time CRISP was initiated in 1991, OSHA exempted construction work from its 1978 lead standard which had lowered the permissible exposure limit (PEL) to 50 $\mu g/m^3$ and added provisions for blood lead monitoring and requirements for medical removal at blood lead levels reaching 50 μg/dl. As a result the PEL of 200 $\mu g/m^3$ for construction workers remained. CRISP anticipated the 1993 OSHA requirements and progressively reduced the medical removal level in each year of the project to levels below those required by OSHA. These lower blood lead level requirements along with the use of contract specifications rather than regulations to achieve health and safety goals are important distinctions between the CRISP program and the subsequent OSHA requirements.

The CRISP approach was first described and contrasted with the 1993 OSHA lead in construction standard by Maurer et al. [1995] who initiated and implemented CRISP. This article further characterizes CRISP and shows that, compared to similar groups of workers protected by the OSHA standard alone, workers from the CRISP program had lower blood lead levels overall.

METHODS

History and Development of CRISP

Yale University proposed this demonstration project which was supported in 1990 by NIOSH. Investigators proposed to demonstrate that workers could be protected and high blood lead levels prevented through contract specifications mandating a comprehensive lead health protection program (LHPP) [Maurer et al., 1995c]. The investigators worked with the Connecticut Departments of Health Services (DHS) and of Transportation (ConnDOT), the Connecticut Construction Industries Association (CCIA), and state construction trade unions to establish contract specifications and the LHPP for which ConnDOT assumed the cost.

From November 1990 through September 1992, CRISP investigators visited several field operations and worked with ConnDOT to finalize the contract specifications. During this time, a 50 μg/dl medical removal requirement and follow-up with on-site personnel was introduced on lead-related bridge project sites [Maurer et al., 1993]. By 1993, specific contract requirements for lead health protection addressing medical surveillance, biological monitoring, day-to-day industrial hygiene and environmental monitoring, specified respiratory protection for particular tasks and hygiene facilities were adopted by ConnDOT and implemented on lead-related projects. The contract specifications and the LHPP supported by ConnDOT also ensured compliance with all relevant OSHA regulations.

In addition, CRISP differed from the 1993 OSHA 29 CFR 1926.62 lead in construction standard, which set a blood lead level of 50 μg/dl for medical removal protection, in that CRISP initially set the medical removal protection level to 40 μg/dl. In 1994, the medical removal protection level was lowered to 35 μg/dl. Then, during 1995 and into the first part of 1996, the medical removal protection level was further reduced to 30 μg/dl. When blood lead levels over 25 μg/dl were detected, the industrial hygiene consultant was responsible for recommending additional protective and hygiene measures to the contractor and if subsequent blood lead levels remained high, medical removal to a lower exposure job was required.

Components of the CRISP Lead Health Protection Program

CRISP ensured compliance through contract specifications and pass-through cost provisions to achieve its health and safety program goals. Specifications required prospective contractors to get at least three bids from industrial hygiene (IH) firms to conduct on-site industrial hygiene and environmental monitoring, provide medical surveillance, biological monitoring, hygiene facilities and respiratory protection for their employees, and to agree to comply with specified ventilation, equipment, and materials [Castler, 1995]. From those three bids ConnDOT selected the IH firm which was then employed and paid as a subcontractor on the job. In addition, CRISP used a centralized system located at the Connecticut Department of Health for managing blood lead and medical monitoring data [Maurer et al., 1995b]. Features of each component were constructed from the synthesis of existing regulatory requirements and the experience of the investigators.

Respiratory Protection

For all projects involving leaded paint, respiratory protection was required. Minimum respiratory protection for tasks that were anticipated to reach certain airborne concentration levels was explicitly written into the contract specification. Prior to the 1993 OSHA standard, this included air-supplied helmets with capes for abrasive blast cleaners, powered air purifying respirator equipped with a high efficiency filter for the vacuum collection, abrasive blast crew, painters, welders and flame cutters [Castler, 1995]. If air-sampling data (e.g., less than 500 μg/m^3) justified lower levels of respiratory protection, half face air purifying respirators were permitted. After the OSHA 1993 standard was promulgated, the specification was changed to require that the procedures for selection of appropriate respiratory protection conform to the new standard.

On-Site Industrial Hygiene Monitoring

CRISP Health and Safety program specifications directed on-site industrial hygiene technicians to conduct personal air sampling every 14 days on selected workers who performed specific tasks such as dust collection equipment operations and filter changes, or at the discretion of the on-site industrial hygienist. Airborne lead dust monitoring was required monthly for the first 3 months for other tasks that pose an airborne lead exposure risk at the work site and on workers who perform tasks where exposures were unknown or unclear. Monthly reports summarized field records and personal air sampling conducted routinely on the contractor workforce by the on-site industrial hygiene technicians. At a minimum, these reports provided results of these samples as 8-hour time-weighted averages as well as information about the task and worker sampled. In many cases the actual sampling time was also provided. Reports also described standard industrial hygiene sampling procedures, equipment, methods, field quality assurance protocol, and accredited laboratories.

Centralized Medical Monitoring and Blood Lead Level Management

Project entry blood lead testing occurred during the initial medical exams. In general, subsequent testing occurred monthly for the first 3 months followed by testing every 3 months and upon exit from the job. If a blood lead level of 25 μg/dl or greater was detected, blood lead testing reverted to monthly intervals. An airborne action level that triggered additional blood lead testing was set at 30 μg/m^3 over an 8-hour period without regard to the use of respiratory protection. Blood sampling was conducted at any of the CRISP approved clinics. Sampling was conducted using the CDC protocol for venipuncture blood draws and an accredited laboratory performed the analyses. These results were reported within 24 h to a centralized location at the Connecticut Department of Health and if blood lead levels were greater than 25 μg/dl, the CRISP industrial hygiene investigator followed up with the on-site contractors and industrial hygiene personnel. If blood lead levels exceeded the threshold (which decreased from 40 to 30 during CRISP), medical removal of the worker was mandated [Maurer et al., 1995a, 1995c].

CRISP Bridge Projects

Thirty-three bridge projects involving workers who were enrolled in the CRISP program were selected. They represented range of start dates, project duration, location, and industrial hygiene firms within Connecticut. They have been classified into three groups according to the major activity performed during the project: (1) paint removal by abrasive blasting methods, (2) ironwork involving torch cutting, burning or welding on painted surfaces, and (3) projects involving both iron work and abrasive blasting.

The CRISP Enrolled Workforce

Information on workers was collected during the initial blood lead sampling. This included demographics, craft affiliation, employer, job location, and recent occupational tasks. This information and ConnDOT records listing the names of companies awarded painting and ironwork contracts were used to categorize workers into employer groups. Ironwork, painting, and general contractors used job titles such as foreman, laborer, and equipment operator. Laborers assisting in an abrasive blast paint removal activity located inside a containment structure were classified with those assisting with road resurfacing. This created a group with more diverse exposure experiences than classifying laborers who work for a painting contractor with painters. Therefore, contract workers and others were grouped according to the major duties performed by their employer. Employer groups consisted of: (1) painting contractors whose employees performed paint removal and reapplication (mainly painters, abrasive blasters, recycling equipment operators, laborers, and foremen); (2) contractors who performed both iron work and abrasive blast paint removal (''mixed worker group''); (3) iron work and welding contractors (iron workers, welders, laborers, and foremen); (4) employers of craft workers (the craft worker group) who performed general duties such as road resurfacing and containment building (e.g., general contract carpenters, heavy equipment mechanics, operators, and drivers and laborers); and (5) employers of engineers and industrial hygiene firms (the professional group) (mainly inspectors, project engineers, and environmental, health, and safety personnel). The fourth and fifth groups comprised workers not directly involved with paint burning, removal or cleanup. Employer groups were determined by matching employee job titles, reported employer and Connecticut Department of Transportation contract award listings. Twenty-three workers had insufficient employer information and were excluded from the analysis.

Non-Connecticut Worker Comparison Groups

Data from workers who work outside Connecticut were obtained for two comparison groups, abrasive blasters and ironworkers. A group of 88 painter/blasters working during 1994 in Connecticut under CRISP were compared to 132 painter/blasters also working in 1994 outside Connecticut and, therefore, not under the CRISP protocol. The latter workers were employed by one of 35 construction companies who contracted with an Ohio physician's clinic to have their workers medically screened during abrasive blasting bridgework in 1994. Each group was screened and periodically monitored for blood lead. Most workers had more than one blood lead test [Maurer et al., 1995c].

In addition, data collected from a group of 85 ironworkers monitored as part of a research project in New York [Levin et al., 1997] was compared to data from 72 CRISP ironworkers that conducted work in 1994. Tasks performed on these projects were similar (i.e., welding, rivet busting, torch cutting, needle gun chipping, and grinding). Each group was screened and periodically blood lead monitored using similar protocols—approximately monthly, using a certified laboratory for analysis.

Statistical Methods

Frequency, average and standard deviation measures were calculated for both bridge project and worker group characteristics. Workers were divided into five broad groups by employer type (see above). The metric of blood lead concentration chosen for evaluation was the maximum level observed for each worker in each year (“peak blood lead concentrations”) as this was the most rigorous test of worker protection. Peak blood lead levels among these groups for each year of the demonstration project were stratified by yearly intervals from 1992 through 1995. The 1992 strata included a few months in 1991 and the 1995 strata included a few months into 1996. Groups were further stratified by first year and continuing (hereafter referred to as return) worker status and the difference in each subgroup average among worker peak blood lead levels was examined.

RESULTS

CRISP Enrolled Bridge Projects

The CRISP program monitored over 90 bridge projects. Thirty-three bridge projects within Connecticut are listed in Table I. Most projects were monitored over multiple years. The largest project involving the greatest number of contract employees began in late 1992 and was monitored into 1996 and included both ironwork and abrasive blast paint removal. Many projects were monitored during 1994 or 1995 that involved 25 or fewer workers. In 1994, approximately equal numbers of ironwork and abrasive blasting projects were monitored, whereas in 1995–1996, many projects involved ironwork only. On bridge projects where information was reported, surface paint had high lead content; on most bridge projects at least one sample contained over 30% lead and the range of maximum sample values was 7–74%. Average levels ranged from 3 to 41% although some of these results came from very few measurements and about 30% of the bridge projects were missing this information in industrial hygiene reports. Three industrial hygiene firms monitored these projects; one firm monitored two-thirds of them.

Characteristics of CRISP Worker Groups

Table II displays the demographic characteristics of and the blood lead levels taken from workers prior to starting work on a CRISP monitored project. Painting contract and mixed workers (i.e., workers who performed both abrasive blasting and ironwork) were hired mostly in 1994 whereas all other groups were hired mostly in 1993. The proportion of in-state workers decreased in all but the ironworker group, which increased over time. This may have been due to the heavy demand for painting contract work in Connecticut during this period of time. The proportion of the workforce that was female remained very low in all groups. The percentage of minority workers increased over time in all but the iron and professional worker groups. The proportion of smokers increased over time among the iron workers and in the group performing both iron work and paint removal by abrasive blasting, but no trend emerged in the other three groups.

Ironworkers showed an increasing trend in average age that was not seen among other workers. The average initial blood lead levels of workers in all three groups performing paint burning, removal or cleanup were more elevated in the early years than in later years of the CRISP demonstration project. The painting contract employees had the highest arithmetic average initial blood lead level of 31 μg/dl in 1991–1992, which decreased to 8.9 μg/dl in 1995–1996. Average initial levels among the professional and craft worker groups continued to be very low (less than 7 μg/dl)

TABLE I. Thirty-three Typical Connecticut Road Industry Surveillance Project Monitored Bridge Projects During 1992–1996[a]

Bridge information			% Lead content						
Project ID	Active years	Lead related work	N	mean	SD	GM	Max	IH firm	No. workers
094–170/171	1992–1996	AB/IW	62	3	(5)	1	19	B	659
103–220	1993	IW	9	24	(4)	24	29	B	20
50–179/181	1994	AB/IW	—	20	—	—	—	B	29
103–217	1994	AB	1	14	—	14	14	B	8
130-151/160	1994	IW	5	34	(6)	34	41	B	8
165–266	1994	IW	6	26	(21)	19	58	B	5
173–223	1994	AB	—	—	—	—	—	C	12
34–235/252	1994	AB	—	—	—	—	—	C	13
159/148/164/165	1994	IW	—	—	—	—	—	C	5
63–458	1994	AB	3	23	(2)	23	25	B	34
83–219/106–104	1994, 1995	IW	17	12	(15)	2	44	B	28
85–124	1994, 1995	AB	30	15	(8)	12	29	B	25
87–131	1994, 1995	AB	64	41	(14)	38	74	B	40
172–244	1994, 1995	IW	24	20	(10)	13	32	B	25
172–251	1994, 1995	AB	—	—	—	—	—	B	15
105–130/182	1994–1996	IW	1	32	—	32	32	B	35
059–134	1994–1996	AB/IW	12	28	(16)	23	57	B	15
171–213	1994–1996	AB	16	32	(15)	18	43	A	37
082–223/252	1994–1996	AB/IW	—	—	—	—	—	C	310
15–211/233	1995	IW	3	18	(2)	17	19	C	7
42–236	1995	IW	—	—	—	—	—	B	14
128–126	1995	AB/IW	—	—	—	—	—	C	4
173–260	1995	AB	7	24	(8)	23	29	B	25
102–239	1995, 1996	AB	6	29	(7)	29	37	B	13
151–246/247	1995, 1996	AB	67	21	(14)	15	69	C	85
15–204/222	1995, 1996	IW	3	31	(22)	23	50	B	11
148–162	1995, 1996	IW	6	11	(3)	10	15	B	2
158–173	1995, 1996	IW	2	4	(5)	2	7	C	5
138–197	1995, 1996	IW	22	7	(10)	1	26	B	5
172–253	1995, 1996	AB	—	—	—	—	—	A	15
124–151	1995, 1996	AB	—	34	—	—	—	C	28
063–376/480	1995, 1996	IW	—	—	—	—	—	B	82
15–232/242	1996	IW	7	19	(18)	12	57	B	13

[a]—, missing information; SD, standard deviation; AB, abrasive blasting; IH, industrial hygiene; IW, iron work; GM, geometric mean.

throughout the entire CRISP observation period. Twenty-three workers with insufficient employer information were mostly Connecticut residents, all male, mostly white smokers in the age range 30–46 years with low initial blood lead levels (5–9 μg/dl) (Table II).

Year-to-Year Peak Blood Lead Levels

The peak blood lead level for each individual worker in each year was identified. This measure was used to represent worst-case levels observed within each worker group during the year. The distribution of the annual peak blood lead level among worker groups, percentiles, and the maximum levels for each worker group during years 1992–1995, and the percent in each group who returned to CRISP-monitored bridge projects are displayed in Table III.

The total number of workers increased in each group over time, and the proportion of workers who returned to CRISP-monitored projects from previous years increased among all but the craft worker group, which decreased from 54 to 41%. Ninety-fifth percentiles of peak blood lead levels ranged from 6 to 74 μg/dl. After 1992, in all groups, half of

TABLE II. Characteristics and Blood Lead Levels by Year Workers Entered Their First Connecticut Road Industry Surveillance Project Monitored Bridge Project and Grouped by Employer Type, 1992–1995 (N = 1950[a])

		Percent				Age (Years)	Initial blood(μg/dl)	
Year	**N**	**CT resident**	**Male**	**White**	**Smokers**	**Mean (SD)**	**Mean (SD)**	**GM**
Painting contract employees								
1992	47	64	100	89	64	35 (9)	31 (21)	24
1993	138	58	96	84	57	36 (9)	12 (11)	10
1994	304	48	97	86	64	33 (9)	12 (9.4)	9.1
1995	229	45	100	76	56	34 (9)	8.9 (7.3)	6.9
Mixed contract employees								
1992	35	100	97	97	46	32 (7)	19 (9.8)	17
1993	43	100	95	88	53	42 (10)	14 (7.6)	12
1994	79	49	89	93	52	35 (11)	9.8 (7.2)	8.2
1995	43	35	95	71	69	34 (11)	6.8 (5.1)	5.9
Ironwork contract employees								
1992	46	67	89	84	39	37 (11)	16 (11)	12
1993	170	72	98	91	44	38 (11)	9.1 (7.1)	7.6
1994	162	95	97	86	51	40 (11)	8.0 (5.3)	7.0
1995	101	96	98	89	50	40 (11)	6.9 (5.9)	5.7
Craft and labor workers								
1992	1	100	100	100	100	38	8	
1993	108	91	98	88	49	37 (10)	7.6 (4.9)	6.7
1994	22	95	95	100	55	39 (10)	5.3 (0.9)	5.2
1995	50	74	98	74	41	36 (11)	6.5 (4.4)	5.6
Professional workers								
1992	8	88	100	100	50	34 (6)	5.1 (0.4)	5.1
1993	131	89	92	91	31	38 (10)	5.6 (1.2)	5.5
1994	107	90	87	92	33	33 (10)	5.6 (3.5)	5.3
1995	103	85	91	89	44	34 (11)	4.5 (4.5)	4.3
Workers with missing employer information								
1992	1	100	100	100	100	40	5	
1993	2	100	100	50	100	46 (6)	9 (1)	9
1994	1	100	100	0	100	30	5	
1995	19	94	100	71	63	34 (11)	6 (4)	5

[a]years 1992 contain a few months in 1991 and 1995 includes a few months in 1996. SD, standard deviation; GM, geometric mean; μ, microgram; dl, deciliter.

the blood lead levels never reached 25 μg/dl. Among the professional workers, 95% of workers had peak blood lead levels less than 12 μg/dl in any year. However, in years 1993–1995 maximum levels of 19, 40, and 32 μg/dl respectively, were reached by three workers (all were Inspectors). Ninety-five percent of the craft worker group never reached 25 μg/dl, while the 95th percentile of the iron-worker group decreased from 36 to 23 μg/dl and the mixed worker group from 44 to 29 μg/dl from 1992 to 1996. Painters experienced the greatest decline, with the maximum falling from 84 to 60 μg/dl in 1992–1996 and the 95th percentile from 74 in 1992 to less than 42 μg/dl in subsequent years. The median levels fell by approximately 50% for the three major lead exposed groups and the median peak blood lead for all workers was 15 or less by 1995 (Table III).

The proportion of painters reaching or exceeding 50 μg/dl (the OSHA medical removal level) decreased from 21% in 1992 to 1% in 1995 (Figure 1).

Note that in Table III, the 50th percentile levels in the painter group sharply decreased from 1992 to 1993 but then slightly increased from 1993–1995. The proportion of

TABLE III. Annual Peak Blood Lead Levels (μg/dl) of Connecticut Road Industry Surveillance Project-Monitored Workers Grouped by Employer Type, 1992–1995[a]

Year	N	% Returned	Percentile 5th	Percentile 50th	Percentile 95th	Maximum
Painting contract employees						
1992	47	—	6	27	74	84
1993	159	13	5	13	40	79
1994	414	27	5	14	41	64
1995	447	49	4	15	38	60
Mixed contract employees						
1992	37	—	9	20	44	50
1993	65	34	6	14	34	38
1994	114	32	5	13	35	43
1995	137	69	3	11	29	39
Ironwork contract employees						
1992	46	—	5	14	36	45
1993	198	30	3	6	31	48
1994	223	27	5	7	21	47
1995	202	50	5	5	23	39
Craft and labor workers						
1992	1	—	8	8	8	8
1993	116	—	5	6	22	27
1994	52	54	5	6	16	32
1995	83	41	3	5	21	27
Professional workers						
1992	8	—	5	5	6	7
1993	148	5	5	5	11	19
1994	188	39	5	5	10	40
1995	201	43	3	5	10	32

[a]years 1992 contain a few months in 1991 and 1995 include a few months in 1996. μg, microgram; dl, deciliter.

workers who returned from a CRISP project conducted in the previous year (and who therefore had higher blood lead levels from past exposures) also increased substantially (over 3-fold from 1993 to 1995). However, when the newly hired and return workers were analyzed together, decreases in blood lead levels from year to year were obscured (data not shown). When analyzed separately, these subgroups each showed noticeable declines. Figure 2 shows changes in the arithmetic average of the peak levels from 1993 to 1995 in the first year subgroup of craft workers and in two subgroups of painters, ironworkers, and professionals. From 1993 to 1995, the mean blood lead level dropped among all first year worker groups. The only subgroups that increased were the two with the lowest blood lead levels, the professional returnees and the craft worker returnees (measured from 1994 to 1995). The average blood lead levels declined the greatest for ironworkers among all subgroups.

Comparison of CRISP-Protected Workers to Non-Connecticut Workers

To examine the effect of the CRISP intervention compared to the presence of OSHA regulations only, persons with a job title of painter/blaster were drawn from painting contractors who worked either under CRISP or on a non-Connecticut abrasive blast paint removal bridge project.

Figure 3 compares the cumulative percent of workers with peak blood lead levels among Connecticut painter/blasters to levels from the painters who worked in a state with only an OSHA program. Both groups were 100% male. The CRISP group was slightly older with a mean age of 37 ± 8 years compared to a mean age of 34 ± 8 years (*t*-test $P = 0.001$) in the non-Connecticut group. Levels were much lower for the CRISP group ($P < 0.001$), with a median of 17 μg/dl and only 1% above 50 μg/dl compared to a

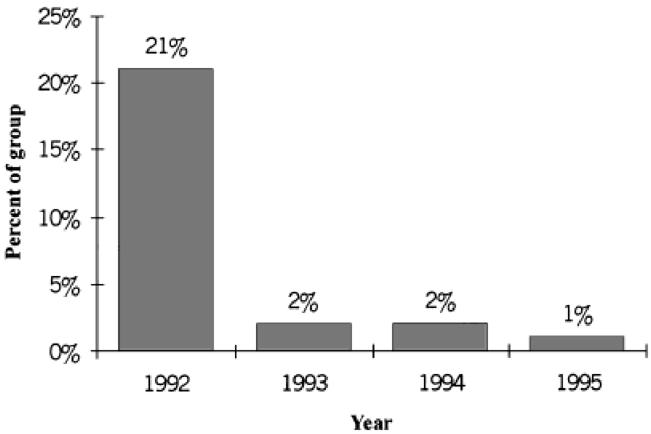

FIGURE 1. Percent of CRISP-monitored painting contract employees who reached or exceeded 50 μg/dl during years 1992–1995 (the OSHA medical removal level). Note that, among this group of workers, peak blood lead levels exceeding 50 μg/dl decreased from 21% in 1992 to 1% in 1995.

median of 34 μg/dl and 21% above 50 μg/dl for the non-Connecticut group. Higher blood lead levels in the non-Connecticut group may be due to the lack of implementation of OSHA worker protection provisions. The extent of OSHA compliance or industrial hygiene oversight among this group is not known.

Figure 4 compares the effect of the CRISP intervention to protection under the OSHA regulations, for ironworkers. Both groups were 98% male and 59% of the CRISP group was at least aged 37 years and 59% of the non-Connecticut group was at least 35 years of age. Levels were significantly lower for the CRISP group ($P < 0.001$), with a median of 9 μg/dl and 100% below 30 μg/dl compared to a median of approximately 12 μg/dl and 94% below 30 μg/dl for the non-Connecticut group. The New York ironworkers were probably better protected than most outside of Connecticut because of the presence of a research team that conducted regular air and blood lead monitoring throughout the year and documented implementation of OSHA worker protection provisions [Levin et al., 1997].

DISCUSSION

CRISP was created during the early 1990s in anticipation of an intense program to rehabilitate Connecticut bridges. Its major goal was to protect and monitor workers known to experience high blood lead levels during bridge repair. Approximately 2,000 workers, and over 120 contractors benefited by the program's success because it substantially reduced the occurrence of high blood lead levels, those that require medical removal protection (50 μg/dl) under the 1978 OSHA General Industry Standard and the 1993 Lead in Construction Standard.

Measures such as average and incremental change in blood lead level have been used by others to report exposures [Maurer et al., 1995c; Levin et al., 1997]. From a

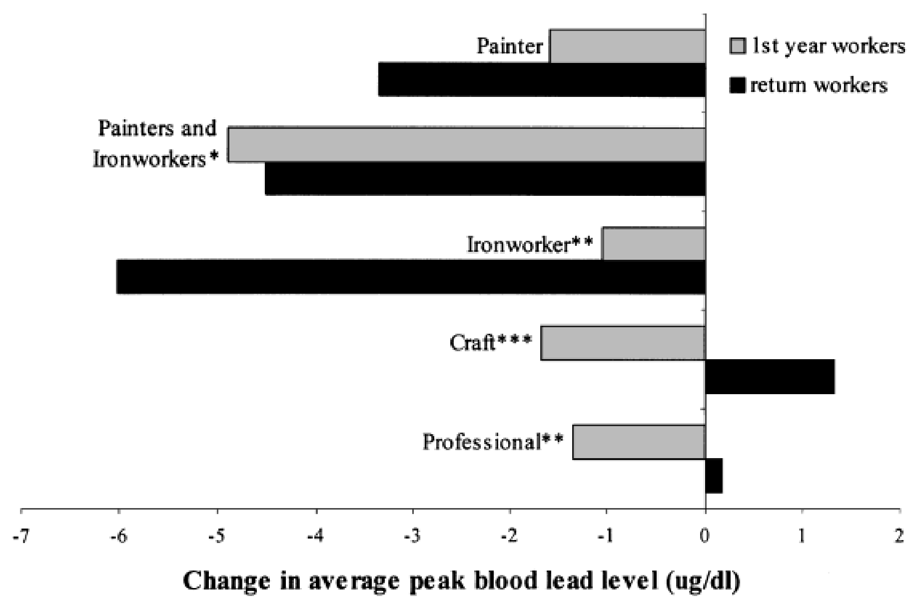

FIGURE 2. Change in average peak blood lead (μg/dl) from 1993 to 1995 in CRISP-monitored newly hired (i.e., first year) workers and those workers who were hired in years prior to 1993 and 1995 (i.e., return workers). Note that the average blood lead levels declined the greatest for ironworkers among all subgroups. *Statistically significant change; $P < .05$ for both 1st year and return worker groups. **Statistically significant change; $P < .05$ for the return iron worker and 1st year professional worker group. ***Due to an insufficient number of return workers in 1994, changes for craft return workers were measured from 1994 to 1995.

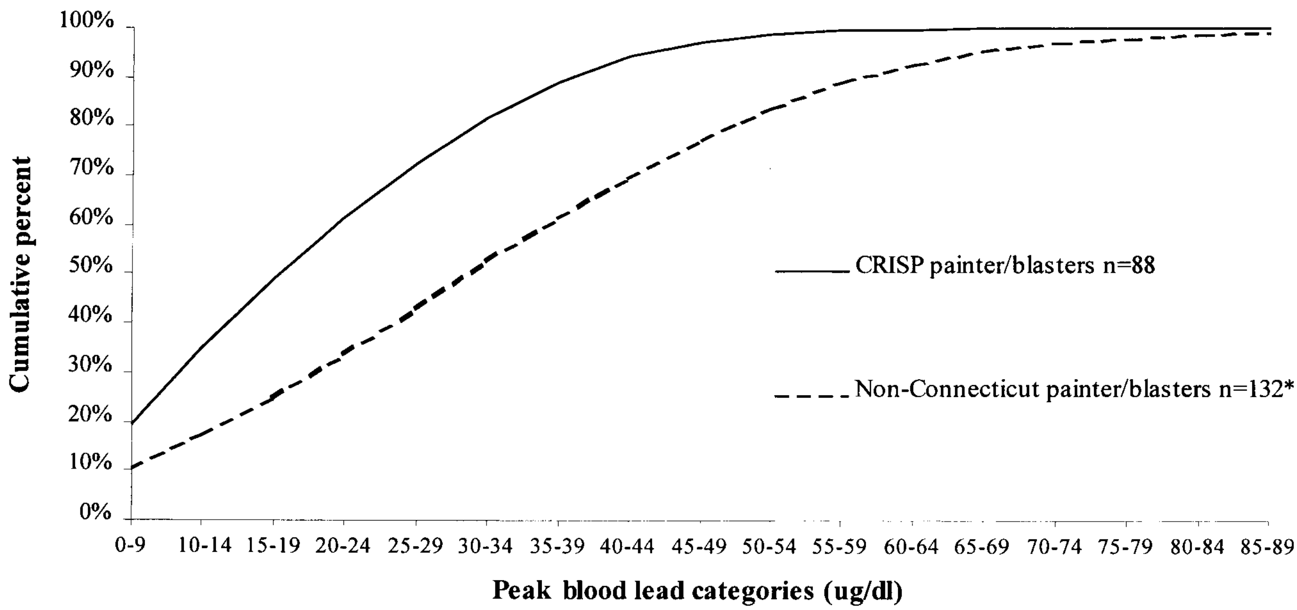

FIGURE 3. The effect of the CRISP intervention on the peak blood lead levels among Connecticut painter/blasters compared to levels from the painter/blasters who worked in a state with only an OSHA program. Note that levels were much lower for the CRISP group ($P < 0.001$ for the test of statistical significance in the difference between groups), with a median of 17 μg/dl and only 1% above 50 μg/dl compared to a median of 34 μg/dl and 21% above 50 μg/dl for the non-Connecticut group. *Statistically significant; $P < .05$.

public health perspective the major goal of CRISP and other lead prevention programs is to ensure that the concentration of lead in the blood is always as low as possible. Therefore, the most rigorous test of the success of this program lies in examining the maximum lead concentration experienced by each worker in each year, and this value, the "peak" blood lead, was the metric chosen for evaluation in this study.

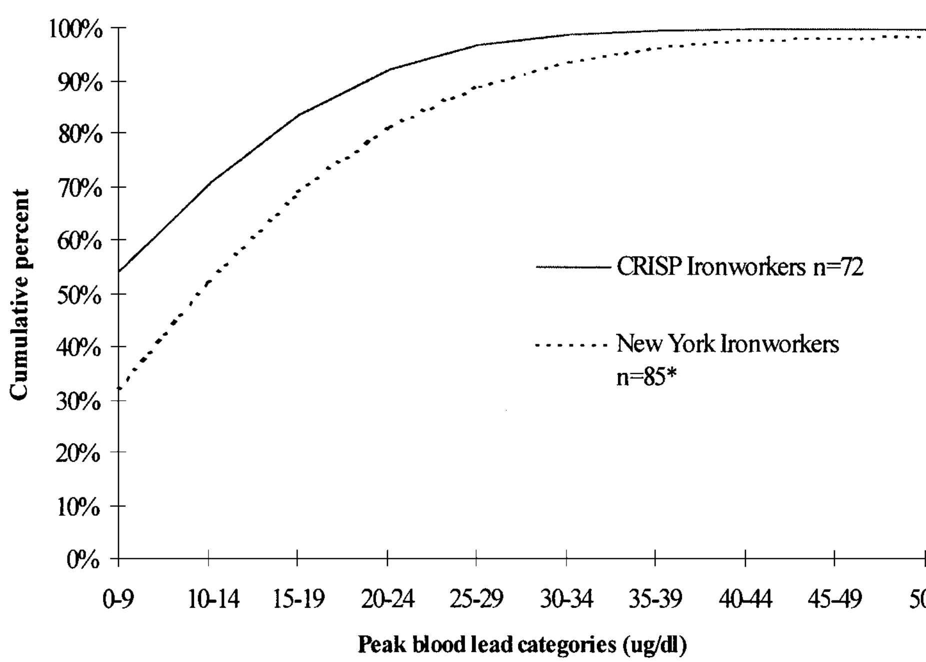

FIGURE 4. The effect of the CRISP intervention compared to protection under the OSHA regulations, for ironworkers. Levels were significantly lower for the CRISP group ($P < 0.001$ from the test for statistical significance in the difference between groups), with a median of 9 μg/dl and 100% below 30 μg/dl compared to median of approximately 12 μg/dl and 94% below 30 μg/dl for the non-Connecticut group. *Statistically significant; $P < .05$

Unlike the experience of blasters and ironworkers in the 1980s and early 1990s with levels in the 80–100 µg/dl range [Landrigan et al., 1982; Fischbein et al., 1984; NIOSH, 1992; Risk et al., 1992; Waller et al., 1992; Frumkin et al., 1993; Osorio and Melius, 1995], over 99% of the CRISP cohort maintained blood lead levels below 50 µg/dl. Within the CRISP cohort, worker blood lead levels decreased over time. This is particularly evident when workers were subdivided by newly hired and returning worker status. The percent of CRISP painters and ironworkers with elevated blood lead levels was also significantly smaller than among compared groups in other states, outside of the CRISP system.

There is limited information about the CRISP and non-Connecticut cohorts beyond the demographic, job title, and blood lead testing characteristics [Maurer et al., 1995c; Levin et al., 1997]. Therefore, the conclusions drawn from these comparisons are stated with caution. Under the assumption that these groups are reasonably comparable, the slight differences in age and frequency of blood lead testing are unlikely to explain the changes in blood lead levels observed in this analysis. In fact, the CRISP workers were older and in the absence of recent exposure, would be expected to have had higher blood lead levels.

A key difference between the current OSHA standard and the CRISP model was the contract specifications mandating the development and implementation of a site-specific health protection program. When spelled out in the contract specifications, health and safety could not be ignored or easily underbid by the contractor; different implementation mechanisms, a system of pass-through payment for costs, and a greater ownership of the health and safety provisions could be created. These features may be absent under a broad requirement of OSHA regulatory compliance.

In 1993 through 1995, when CRISP covered nearly all bridgework in Connecticut, there were several smaller projects (e.g., had 25 or fewer workers) that were likely to entail sporadic and frequent relocation. The CRISP centralized blood lead monitoring and follow-up may have also played a key role in reducing higher blood lead levels by providing continuity of health care and early intervention for this easily overlooked group of workers.

A recent study sponsored by the National Cooperative Highway Research Program reveals there is a high degree of variability in contractor practices and technology among state and local highway agencies for removing lead paint from bridges [Appleman, 1998]. The Connecticut specifications required particular work practices, equipment, and materials during lead-related bridge projects. These requirements may have contributed to or prevented exposures observed in similar projects conducted without these specifications. For example, all ConnDOT bridge projects involving the abrasive blasting of lead-based paint were conducted dry. This procedure required Steel Structures Painting Council Class 1 or 3 containment enclosures with additional requirements for sealing in debris and a minimum negative pressure with airflow through the enclosure required under the OSHA ventilation standards [Castler, 1995]. General ventilation during dry abrasive blasting operations has not been found to be an effective means of controlling airborne concentrations of lead to levels that have been observed by wet methods, vacuum blasting or chemical stripping, which produce considerably less airborne dust [Mickelsen, 1995; Mickelsen and Johnston, 1995; Mickelsen and Haag, 1997; Frenzel, 1998]. Needle guns were used for small jobs. Compared to abrasive blasting, this technology would have substantially reduced the airborne concentrations of lead generated during removal operations [Randall et al., 1998].

Other requirements may have provided greater protection for workers. For example, all abrasive blast material was required to be recyclable steel grit, contamination of abrasive mix was not permitted to exceed 0.1% by weight, and total lead content was not to exceed 200 parts per million [Castler, 1995]. Compared to other abrasives such as copper slag, steel grit produces much lower airborne concentrations of lead [Adley and Trimber, 1999].

Numerous studies have examined the cost, efficiency, and effectiveness of various technologies for lead paint removal [Mickelsen, 1995; Mickelsen and Johnston, 1995; Bates, 1996; Smith, 1996; Mickelsen and Haag, 1997; Frenzel, 1998; Randall et al., 1998]. These and other issues such as the competing interests of environmental protection and challenges related to bridge location and the area where paint removal takes place may also affect worker exposures [Seavey et al., 1996; Zamurs and Bass, 1998; Huffman, 1999]. Further research is needed to evaluate the relative impact of these and other work-related conditions that may impact worker exposures. In Connecticut during CRISP, factors such as air and surface dust lead content at work sites, containment characteristics, hygiene practices, and facilities and administrative practices varied among bridge projects. We are currently examining such factors for further clues to the essential components that reduced worker blood lead levels overall.

CRISP is an effective strategy that continues to be implemented in Connecticut (with some modifications) and could serve as a model for other programs. Copies of the LHPP specifications can be obtained from the ConnDOT web site: http://www.state.ct.us/dot/bureau/eh/ehen/stdes/br/files/specs/accept.html under item number 603271A.

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