

Effectiveness of the Training Program for Workers at Construction Sites of the High-Speed Railway Line Between Torino and Novara: Impact on Injury Rates

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Background *There are very few published studies evaluating the impact of safety and health training on injury outcomes in the construction industry. The aim of this study was to assess the impact of the training program on injury rates at a major railway construction project.*

Methods *The population consisted of 2,795 workers involved in a safety training program at the construction sites of the high-speed railway line Torino–Novara. Two types of analyses were carried out in order to assess the effectiveness of the training program in reducing the number of injuries: (i) a pre–post analysis, which took into account the fact that workers were enrolled at different times and the training intervention did not occur at the same time for all subjects; (ii) an interrupted time-series model, which corrected for the time trend and considered the autocorrelation between individual observations.*

Results *Twenty-nine percent of workers who spent at least 1 day at the construction sites attended at least one training module. Pre–post analysis: At the end of the training program, the incidence of occupational injuries had fallen by 16% after the basic training module and by 25% following the specific modules. Time-series model: Training led to a 6% reduction in injury rates, which was not statistically significant.*

Conclusions *The training program that was implemented had a moderately positive impact on the health of workers. Further studies are being conducted to obtain a more complete assessment of the actual effectiveness of the program in reducing the incidence of injuries. Am. J. Ind. Med. 52:965–972, 2009. © 2009 Wiley-Liss, Inc.*

KEY WORDS: *injury rates; training program; construction; intervention study; occupational safety*

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INTRODUCTION

Developing and implementing safety training programs in the workplace is of technical importance and social relevance. This is especially true for the construction industry, in which the work to be performed and the actual working conditions are extremely varied and changeable, as are the risks to which the workers are exposed. Moreover, the construction industry is consistently reported, in Italy and internationally, as having one of the highest injury incidence

and severity rates [European Communities, 2004; Italian National Institute of Insurance for Occupational Accidents, 2008].

Training programs as part of a health and safety management strategy must be designed to change unsafe habits and promote safe ones. They must integrate the technical and organizational aspects of safety but cannot make up for technological or organizational shortcomings or any lack of facilities (definition of procedures, jobs, and responsibilities). There are many and varied determinants of injury risk in the construction industry, including knowledge of safety measures and familiarity with the job (possible training objectives) plus many others that training cannot alter.

In the field of safety management, training must not only “pass on” technical notions and information but also: (i) raise risk awareness; (ii) ensure correct understanding of the relationship between action, danger, and risk; (iii) improve the understanding of risk management; (iv) improve the understanding of safety requirements.

Thus, safety training increases the technical and professional skills associated with the way different tasks are performed (“knowing how to do something well”) but must also develop “cross-disciplinary skills.” These include the ability to learn from experience, to communicate, to make decisions, to recognize own limits, and to share knowledge and capabilities (networking).

Although it may appear intuitively obvious that raising laborers’ safety and health awareness will reduce their risk of injury on the job, there are very few published studies evaluating the impact of safety and health training on injury outcomes in the construction industry [Kinn et al., 2000; Dong et al., 2004]. A review by the NIOSH proposed that training can attain objectives such as increased hazard awareness, among the worker groups at risk, knowledge of and adoption of safe work practices, and other positive actions that can reduce risk and improve workplace safety, but the contribution of training to the reduction of injury rates remains uncertain [Cohen et al., 1998].

The recent Cochrane review regarding the construction industry in particular did not select any studies of this type [van der Molen et al., 2007]. Indeed, it is difficult to evaluate the effectiveness of training due to the intrinsic characteristics of the type of work and the way this is organized: short-term employment contracts, specific and temporary production sites, the simultaneous presence of several firms, many of which are small, the variability of the activities undertaken. These problems, along with ethical considerations, also affect the possibility of defining a “control” group for comparison.

In mid-2002 construction work started on the new high-speed/high capacity Torino to Milano railway line. The section between Torino and Novara, to which this study refers, is 83 km in length and includes more than 15 km of

viaducts and bridges, 3 km of cut-and-cover tunnels, and a multitude of other works on the public road system. Construction work on this section lasted 4 years and was completed in early 2006. Although the exact number of firms that were involved is not known, they are estimated to have numbered over 1,000, 651 of which were authorized under Italian law, for a total of over 10,000 workers. Given the large number of firms involved (651), the Public Authorities (the Piedmont Regional Council and the Public Prevention system) were involved in safety management. The Piedmont Regional Council signed a protocol with the entity responsible for the planning and construction of the high-speed rail network in Italy (the General Contractor), whereby all workers at the construction sites were to be involved in a training program.

The characteristics of the program were to be standardization, appropriateness, and continuity, and its aim was to raise workers’ awareness of the specific risks on this section of the line and provide them with adequate competence in the most important measures for preventing and controlling those risks.

The training program was accompanied by an impact assessment scheme to measure its effects in terms of a reduction in work-related injuries. Data were obtained from the Regional Epidemiological Observatory (Orme-TAV), which is the department of the Piedmont Regional Council established to: (i) monitor work injuries, (ii) collect administrative data about the activities undertaken by construction firms, and (iii) collect information about safety implemented by the firms at the construction sites and the various accident prevention organizations involved in safety management.

The aim of this study was to assess the impact of the training program on injury rates.

MATERIALS AND METHODS

Training Program

Training is one of the main methods used to promote occupational safety by the Piedmont Regional Council in conjunction with the Public Prevention System and in accordance with the construction firms. The overall activity was governed by a specific Technical Implementation Protocol signed by the General Contractor, the Piedmont Regional Council, and the Public Authorities concerned. The protocol defined the operational methods, implementation procedures and criteria, language coding, and also regulated relations among the above parties.

The training program was developed starting from an analysis of ongoing experiences and the identification of the determinants of the occupational accident risk using the PRECEDE-PROCEED model [Green and Kreuter, 2004]. It adopted an andragogic approach [Knowles, 1989]. The

training program was developed and designed to respond to the needs for training identified by analyzing demand and requirements (see the Supplemental Appendix). It was also constructed to make maximum use of active teaching methods appropriate for training adults, to encourage the involvement and participation of all subjects, and combine classroom theory with experience at the construction site.

The program involved eight teams of teachers, including specialists and experts from various institutions or from the General Contractor's firm. They attended a teachers' training course. Their objective, besides providing technical information, was to act as educational leaders/facilitators, paying particular attention to the classroom climate and any unwillingness to learn, helping subjects to recognize the relationship between actions and outcomes, to make them more responsible, raise their awareness of the importance of developing good habits and encourage positive changes.

All the teachers were involved in the planning and shared preparation of the teaching material.

Because injury risk varies by type of work [Lowery et al., 1998, 2000], the training program consisted of a basic module for all workers, and four specific modules addressing the different roles and jobs, structured according to the main risks involved in each activity. Each module consisted of two parts, each lasting 2 hr. At the end of the second part, the worker had to pass a learning test. Depending on their specific job, each worker was invited to attend several modules, starting from the basic module and then going on to complete the specific modules for the activity to be performed at the construction site. Usually, workers were required to pass the basic module test before being able to attend the specific modules (Table I). Special modules were also available for supervisors, fire-prevention, and emergency workers. These modules were excluded from the assessment dealt with in this article.

At the time that the courses were held, a process assessment was conducted to measure quality in terms of:

efficiency, that is, good use of resources; satisfaction and effectiveness with regard to learning; changes in habits; actual improvement of safety at the construction site (see the Supplemental Appendix). The aim was to monitor the overall project to highlight strengths and weaknesses, with a view to making the necessary adjustments during the course of the program to improve teaching activities and define keys for interpreting the results. The program was considered a useful tool for delivering new notions and for improving skills and abilities and taught workers how to work in safety using methods applicable to the everyday context.

Study Population

From 2002 to 2006, 10,289 worker-jobs were engaged in manual work at the construction sites of the Torino to Novara section of the high-speed railway line. If workers performed more than one job, they were counted for the number of times equal to the jobs performed in the various periods of work. All workers and apprentices operating on the sites were invited to participate. This study concerned 2,795 workers involved in the training scheme. Table II describes worker-jobs by job and type of training module. Table III shows the number of worker-jobs trained per month for both basic and specific modules.

Work-Related Injuries

Injury data were collected by Orme-TAV from the Workers' Compensation Authority (INAIL) and the Public Prevention System. Moreover, the injured worker's firm forwarded the main contractor a copy of the injury report that was transmitted to the Workers' Compensation Authority. Finally, the main contractor sent this information to Orme-TAV. The Workers' Compensation Authority, the Public Prevention System, and the firms were then requested

TABLE I. Description of the Training Scheme*

Type of module	Name of module	No. of enrollments	
Basic modules	Part A	2,682	
	Part B	2,632	
Specific modules	Drivers, excavating machine operators, wheel loader drivers, construction machinery operators	Part A	196
		Part B	191
	Carpenters, iron workers, pump operators, bricklayers	Part A	1,125
		Part B	1,056
	Crane operators	Part A	34
		Part B	38
	Mixed module	Part A	55
		Part B	53

*The number of enrollments does not match the number of workers involved in the training scheme (2,795), because several did not attend one or both basic modules and were therefore enrolled more than once. Furthermore, occasionally, workers attended specific modules before basic modules.

TABLE II. Distribution of Overall and Trained Worker–Jobs by Job and Type of Training Module*

Risk group	Jobs	Worker–jobs					
		Worker–jobs		Basic modules		Specific modules	
		N	%	N	%	N	%
Construction workers	Site supervisor	116	2.33	1	0.07	0	0
	Carpenter	2,531	50.9	1,207	80.85	776	84.16
	Bricklayer	1,234	24.81	184	12.32	104	11.28
	Iron worker	753	15.14	69	4.62	23	2.5
	Pump operator	35	0.7	29	1.94	19	2.06
	Unknown ^a	304	6.12	3	0.2	0	0
	Total	4,973	100	1,493	100	922	100
Machine operators	Driver	1,430	47.73	273	45.73	73	40.78
	Construction machinery operator	695	23.2	160	26.8	73	40.78
	Crane operator	342	11.41	91	15.25	27	15.08
	Excavating machine operator	406	13.55	46	7.7	3	1.68
	Delivery person driver	15	0.5	15	2.51	0	0
	Wheel loader driver	107	3.57	12	2.01	3	1.68
	Miner	1	0.03	0	0	0	0
	Total	2,996	100	597	100	179	100
Maintenance workers	Mechanic	131	28.93	64	40.5	18	35.29
	Warehouseman	71	15.67	30	18.99	11	21.57
	Electrician	106	23.4	29	18.35	12	23.53
	Electrical workshop supervisor	6	1.32	2	1.26	0	0
	Welder	49	10.82	18	11.4	7	13.73
	Field survey assistant	27	5.96	9	5.7	3	5.88
	Painter	4	0.88	3	1.9	0	0
	Plumber	6	1.32	3	1.9	0	0
	Mechanical workshop supervisor	9	1.99	0	0	0	0
	Fitter	44	9.71	0	0	0	0
	Total	453	100	158	100	51	100
Unskilled workers	Total	1,867	100	127	100	12	100
Total ^a		10,289	100	2,375	100	1,164	100

*The total number of worker–jobs involved in the training scheme is lower than the sum of enrolments in Table I since several workers failed the final examination and were thus enrolled more than once.

^aWorkers whose job was not known were included in the largest group.

to provide additional information, which was used to verify the presence of discrepancies among these data sources.

For each injury the following information was obtained: general data, the site at which the injury occurred, days of absence from work, and a description of the injury.

In the period under investigation, 2,086 injuries occurred involving workers at construction sites, including those who had never taken part in the training program. Injuries not recognized by the Workers' Compensation Authority, road traffic injuries, commuting injuries, which would not have been affected by the training program, and fatal injuries were excluded. A total of 1,568 injuries were reported for trained workers: of these, 955 were sustained by subjects who had attended the training program and had achieved the minimum

“basic module” level; 613 involved workers who had taken part in the training program and had attained the minimum “specific module” level.

Statistical Analysis

Analysis was performed using a before and after design without a control group to calculate the injury rate. The *worker–job* was considered as the statistical unit. Risk exposure was calculated in days based on the dates of recruitment and laying-off of each single worker–job, subtracting holidays and days of absence due to injury from the number of working days. Two different types of analyses were carried out.

TABLE III. Number of Worker–Jobs Trained Per Month

Year	Worker–jobs trained											
	January	February	March	April	May	June	July	August	September	October	November	December
Basic modules												
2002	—	—	—	—	—	—	42	—	151	124	68	102
2003	89	22	37	120	189	160	151	6	79	38	14	91
2004	11	12	337	179	9	58	128	13	57	29	3	7
2005	2	4	12	1	1	4	23	—	—	1	1	—
Specific modules												
2002	—	—	—	—	—	—	—	—	—	—	—	—
2003	—	—	—	—	—	—	55	—	117	31	1	1
2004	41	125	14	4	109	121	134	9	11	150	52	40
2005	19	15	72	—	1	—	39	—	—	1	1	1

Model 1

A pre–post analysis was considered. Since workers were enrolled at different times and the training intervention did not occur at the same time for all subjects, the pre-training and post-training periods were calculated for each worker. The pre-training period was that between the date of starting work and the “date of training.” The post-training period was that between the “date of training” and the date of completion of work at the high-speed railway line construction sites. The effects of the basic and specific modules were analyzed separately. (For the basic module a worker–job was operationally defined as a *trained worker* from the date of passing the basic module test. For specific modules the *date of training* was attributed on the basis of the modules each worker had attended, at the end of the training course for the specific job. The worker–job was operationally defined as a *trained worker* from the date of passing the test for the specific module.) The statistical analysis was restricted to trained workers and results were stratified by job. Statistical significance was measured using a *t*-test.

Model 2

Following the guidelines of “The Cochrane Collaboration,” an interrupted time-series model (ITS) was used to assess the effect of the training intervention. The ITS approach is based on the use of time-series regression models, correcting for the time trend and considering any autocorrelations between individual observations. A first-order autoregressive model was defined for quarterly injury rates, using the following parameterization [Ramsay et al., 2003]:

$$Y = \beta_0 + \beta_1 \times \text{Time} + \beta_2 \times (\text{Time} - p) \times I(\text{Time} > p) + \beta_3 \times I(\text{Time} > p) + e$$

where *e* is Normal (0, s^2) and $I(\text{Time} > p)$ is the characteristic function equal to 1 if Time is greater than the intervention time *p*, and 0 otherwise. Since workers did not start the program on the same date, but training was provided over subsequent periods, the intervention time *p* was established as October 1, 2004, which coincided with the moment in time when 88% of the workers had been trained on a specific module. The time period considered was from January 1, 2003 to March 31, 2006, during which the cohort of workers was large enough to guarantee the stability of estimates.

Human Subjects Review

A policy of waived consent, which adhered to the principle of implied consent, was approved by the institutional review board of Piedmont Region. This waiver of informed consent followed the guidelines specified by Italian regulation.

RESULTS

Model 1

In the period from 2002 to 2006, 2,375 worker–jobs reached a basic level of training and 1,164 passed the test of a specific module appropriate to their job. At the end of the training program the incidence of occupational injuries had fallen by 16% (*P*-value: 0.009) and 25% (*P*-value: 0.003), respectively (Table IV).

By stratifying the analysis for the four groups of jobs regarded as being the same in terms of the type of work and risk exposure as defined in Table II, at the end of the training program the frequency of occupational injuries in the “construction workers” group had fallen by almost 21% (*P* = 0.003) among workers who had completed the “basic

TABLE IV. Frequency (Per 10⁴ Days of Exposure) of Occupational Injuries Among Workers Who Had Passed the Basic and Specific Module Test (Overall and Stratified by Job)

Job	Workers (N)	Worker-jobs (N)	Days of exposure		No. of injuries		Frequency (per 10 ⁴ days of exposure)		% change	P-value
			Pre-training	Post-training	Pre-training	Post-training	Pre-training	Post-training		
Basic modules	2,320	2,375	250,769	979,907	224	731	8.93	7.46	-16.49	0.009
Specific modules	1,158	1,164	362,389	345,367	358	255	9.88	7.38	-25.26	0.003
Basic modules										
Construction workers	1,474	1,493	145,448	611,204	169	563	11.61	9.21	-20.72	0.003
Machine operators	568	597	69,170	259,572	31	112	4.48	4.31	-3.72	0.844
Maintenance workers	157	158	17,933	72,686	8	31	4.46	4.26	-4.04	0.905
Unskilled workers	121	127	18,218	36,445	16	25	8.78	6.86	-21.89	0.431
Specific modules										
Construction workers	917	922	263,408	279,822	296	231	11.24	8.25	-26.54	0.002
Machine operators	178	179	70,100	50,898	46	22	6.56	4.31	-34.25	0.192
Maintenance workers	51	51	25,910	11,117	11	1	4.2	1.8	-57.62	0.319
Unskilled workers	12	12	2,971	3,439	5	0	16.8	—		

module” level of training and by 26% ($P = 0.002$) for those who had completed the “specific module” level (Table IV). Among “unskilled workers” with “basic module” training the injury rate fell even more, by 22%, although this result was not statistically significant. For “machine operators” and “maintenance workers” the injury frequency rate fell by around 4% after training among workers who had completed the “basic module” level of training and by 34% and 58% for those with “specific module” training, although these findings were not statistically significant.

Model 2

Figure 1 shows the trend in fall of the phenomenon. All the coefficients estimated by the ITS model revealed a reduction in the risk of injuries. ITS model estimated four coefficients. A first one ($\beta_1 = -0.0031$, $SD = 0.26$) represents the trend of the phenomenon prior to training, a second one ($\beta_2 = -0.67$, $SD = 0.40$) expresses the difference between the post-intervention and pre-intervention period, while a third coefficient ($\beta_3 = -1.88$, $SD = 1.63$) represents the difference between the rate observed in the first post-intervention period and the predicted rate if no training had been provided. Finally, a model intercept ($\beta_0 = 9.65$, $SD = 3.18$) was given. From the model could be estimated that training led to a 6% reduction in the number of injuries, which was not statistically significant ($P = 0.08$).

DISCUSSION

Using the pre–post design, we measured a statistically significant reduction of 16% in the incidence of injuries

among workers who had attended the basic modules, and a 25% reduction for those who completed the training course and also attended the specific modules. In the construction workers group (which represented 63.5% of trained workers) the reduction was 21% and 27% for the two groups, respectively.

The main limit of these results lies in the fact that the impact on the frequency of occupational injuries could be due to other variables and not training. Of these, the most

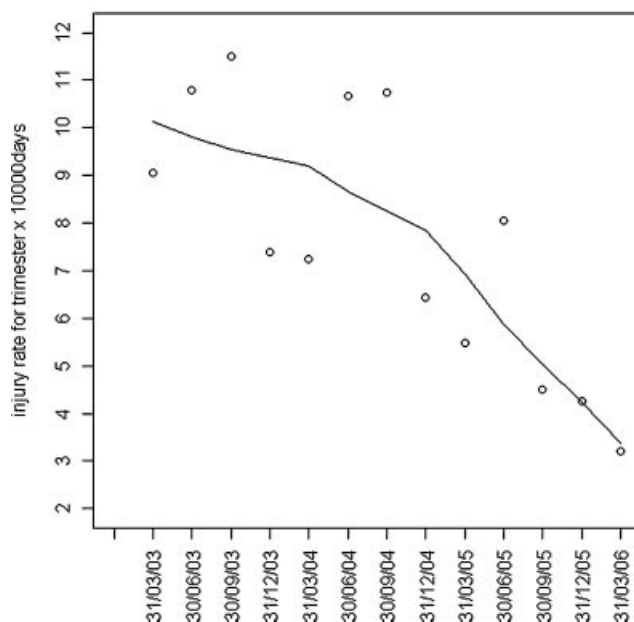


FIGURE 1. Trend in time of quarterly accident rates.

important is the variability typical of construction processes, which could eventually lead to changes in risk exposure conditions. The scientific literature concerning injuries at the workplace points out how different risks characterize the various types of work [Lowery et al., 2000; Spangenberg et al., 2002]. These follow from one another, with the greatest exposure to risk, and thus the expected highest risk of injuries, usually coinciding with the construction of primary structures (viaducts and cut-and-cover tunnels in the case of the Torino to Novara high-speed railway line). The expected risk of injury decreases toward the end of the works. This study primarily avoided that source of confounding with the method used to calculate the training date. This date differed from one worker to the next and was spread over the entire period of observation (Table IV), so that risk exposure in the pre- and post-training periods was not collinear with the sequence of the various phases of work at the construction sites.

The ITS model also considered other “omitted” variables for which no direct measurements are available (type of work, seasonal fluctuations, distribution of workers by age, etc.). All the coefficients estimated by the model revealed a reduction in the risk of injuries. In percentage the reduction was 6%, which was not statistically significant.

The considerable difference between this result and that of the first model might be due to the absence of an actual pre-intervention period. The workers achieved different levels of training (basic or specific) throughout the entire period of the investigation (Table IV). In the period regarded by the test model as the pre-intervention period (from January 1, 2003 to October 1, 2004) several workers had already completed the training course. The injury rate in the pre-intervention period thus involved both untrained workers and partially or fully trained workers, with an overall effect of biasing the pre–post difference toward zero.

There is also a risk of *contamination* due to the simultaneous presence of untrained workers at the same construction site, who may have *negatively influenced* their colleagues who attended the courses, hampering the implementation of safe practice interventions. Only 11% of the workers at the construction sites actually completed the training course with the specific modules. This would also tend to flatten the pre–post difference.

The impact of the training program measured using the ITS design was not statistically significant. Similar studies conducted in other countries have obtained similar results [Spangenberg et al., 2002; Darragh et al., 2004]. However, since injuries are statistically rare events, similar schemes involving a larger number of workers might achieve more significant results.

The short period covered by the investigation might also have affected the results. Construction sites are, by definition, temporary places of work, where several firms are present at the same time to undertake work for short periods. On

average, trained workers were present at construction sites for 10 months, while a systematic training program could have a greater impact if measured in the long term [Gangwar and Goodrum, 2005].

It might have been possible to overcome some of the above limits and gain a better understanding of the true impact of the training program by conducting a randomized study to compare the trained workers with a group of workers who were not involved in the training program. However, randomization is not easily applicable in cases like this, as barring some workers from training courses is not acceptable, mainly for organizational and ethical reasons. Nor can workers at other construction sites be used as a control group, since injury rates at other sites can differ greatly due to characteristics such as age, nationality, job, size of the company. This was shown, for example, in the study carried out during the construction of the Oresund Link between Denmark and Sweden [Spangenberg et al., 2002]. The comparison cannot be made with national estimates because of differences in the reporting systems [Glazner et al., 1998]. In actual fact, the frequency of injuries recorded at construction sites on the Torino to Novara high-speed railway line differed considerably from the general rate of injuries recorded in the construction industry in Italy [Bena et al., 2008].

This study did not have a control group due to the context of the training program. The Piedmont Regional Council signed a protocol with General Contractor whereby the scheme was to include all workers at the construction sites in order to provide a standardized and specific type of training. Despite the ambitiousness of the project, only a portion of workers completed the training course. Non-trained workers were employed in smaller sub-contracting firms and had shorter employment contracts. Furthermore, the non-trained group included a high percentage of unskilled workers (analysis not shown).

Albeit they certainly constitute a selected group, numerous workers could have been included in a control group. Further analyses are underway in which the propensity score matching method [Rosenbaum and Rubin, 1983]—introduced to analyze ex post the impact of rates of pay—will be used to select a control group from among the group of untrained workers as comparable as possible with the group of trained workers in terms of periods of work.

In conclusion, the training program implemented at the construction sites of the Torino to Novara high-speed railway line had a moderately positive impact on the health of workers. Further studies are being conducted to obtain a more complete assessment of the actual effectiveness of the program in reducing the incidence of injuries. Given the methodological difficulties encountered in conducting randomized studies in this field, the use of qualitative and observational methods to assess workers’ ability to implement what they have learned would also be helpful. Our

results underline the need, during safety training implementation, to pay attention to smaller firms with short-term contracts. These firms had more problems with attending the training program. The training program addressing construction sites for the Torino to Novara high-speed railway line systematically reached and certified a large number of workers and can thus contribute to improving safety at construction sites in general, regardless of the impact on the incidence of occupational injuries described in this study. We are now conducting further research on this subject.

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