Original article DOI: 10.1515/aiht-2016-67-2687

Key factors contributing to accident severity rate in construction industry in Iran: a regression modelling approach

Ahmad Soltanzadeh[1], Iraj Mohammadfam[2], Abbas Moghimbeigi[2], Mahdi Akbarzadeh[2], and Reza Ghiasvand[3]

School of Public Health, Qom University of Medical Sciences, Qom, Iran[1], School of Public Health and Research Center for Health Sciences, Hamadan University of Medical Sciences, Hamadan, Iran[2], Institute of Basic Medical Sciences, University of Oslo, Oslo, Norway[3]

[Received in June 2015; CrossChecked in June 2015; Accepted in March 2016]

Construction industry involves the highest risk of occupational accidents and bodily injuries, which range from mild to very severe. The aim of this cross-sectional study was to identify the factors associated with accident severity rate (ASR) in the largest Iranian construction companies based on data about 500 occupational accidents recorded from 2009 to 2013. We also gathered data on safety and health risk management and training systems. Data were analysed using Pearson's chi-squared coefficient and multiple regression analysis. Median ASR (and the interquartile range) was 107.50 (57.24-381.25). Fourteen of the 24 studied factors stood out as most affecting construction accident severity ($p<0.05$). These findings can be applied in the design and implementation of a comprehensive safety and health risk management system to reduce ASR.

KEY WORDS: *accident analysis; ASR; individual factors; organisational factors; risk management; safety; training*

Construction industry involves a high risk of occupational accidents and bodily injuries (1-4). The most common causes include continuous changes in construction design, worksites crowded with people and materials, poor working conditions, non-continuous or cross-seasonal work, manual material handling, outdoor work, direct exposure to weather, and environmental pollutants such as noise, vibration, and dust (5-8). These often lead to occupational accidents such as falling, slipping, collision and crash, chemical exposure, electrical shock, and abrasion.

Today, the use of risk management systems (RMS) reduces the risk of occupational accidents. Traditional and non-systematic methods previously used by contractors are gradually being replaced by systematic and reasonable risk management strategies. These changes bring improvements in different aspects of safety such as risk avoidance, risk transfer, and eventually less injuries and deaths (9).

Yet poor implementation and blind spots in safety and health (S&H) risk management seem to account for as many as 84 % of construction accidents (10). Safety and health management in the construction industry may be affected by poor organisation, financial constraints, non-systematic risk management, deficiency or lack of information about the risks and related accidents, absence of an accident analysis, poor risk assessment, and insufficient health and safety training, which includes low participation of workers in safety programs (11-12).

Iran as a developing country has many construction companies. According to statistics, many accidents at construction sites have resulted in great human and socio-economic losses (2, 4, 13). Although less than 12 % of Iranian workers are active in construction, the severity of injuries is very high (14).

Extensive efforts have been made to distinguish construction accidents and identify factors that lead to them (15-16), but the vast majority of studies are not comprehensive in this respect. Accident severity rate (ASR) is a basic quantitative index of occupational accidents that focuses on their consequences and severity (17). Identifying factors associated with the severity of construction accidents may help to reduce and prevent them. The aim of our study was to cover as many factors identified in accident reports as possible and establish their association with ASR.

METHODS

This cross-sectional study analysed occupational accidents at 13 largest Iranian construction industries

Correspondence to: Iraj Mohammadfam, associate professor, Department of Occupational Hygiene Engineering, School of Public Health and Research Center for Health Sciences, Hamadan University of Medical Sciences, Hamadan, Iran, E-mail: *mohammadfam@umsha.ac.ir*

between 2009 and 2013 that resulted in injury of 500 workers. The analysis included ASR as the dependent factor and individual and organisational factors (IOFs), safety and health training factors (TFs), and risk management factors (RMFs) as independent factors.

Individual and organisational factors

Individual factors included age, working experience, and educational (academic or non-academic) level of the injured workers. Organisational factors included job title (simple construction workers, technicians, or drivers), type of activity that led to the accident (construction work, mechanical activity, installation, and electrical activity), and number of workers (10).

Safety and health training factors

The TFs included pre-employment training (yes/no), periodic training (yes/no), past-accident training (yes/no), training about personal protective equipment (PPE) (yes/no), housekeeping training (yes/no), duration and content of provided safety and health training (acceptable/unacceptable).

Risk management factors

Risk management factors included:

establishment of a system related to S&H (yes/no);

implementation of a risk management system (yes/no);

hazard identification (HAZID) (yes/no);

periodic risk assessment (yes/no);

reporting; implementing report system of all incidents(yes/no);

accident investigation; implementation of any method to accident investigation (yes/no);

S&H-related checklist; completion of checklists about workplace harmful agents or hazards (yes/no);

S&H audit and inspection (yes/no);

PPE; using and wearing personal protective equipment (yes/no);

housekeeping; implementation of proper layout system to place equipment, tools and materials in workplace (yes/no);

toolbox meetings (TBM) at the beginning and the end of the work shift (yes/no).

Accident severity rate

Based on days lost to injury this index has been applied to measure safety performance and identify issues (17). To calculate ASR, we used the formula of the Occupational Safety and Health Administration (OSHA), as follows:

$$ASR = \frac{\text{total number of days lost} \times 200000}{\text{total number of hours worked}}$$

Study step 1: accident data collection

We collected ASR, IOF, TF, and RMF data from accident investigation reports and reports which included information about S&H management, training, interviews (witnesses, supervisors, managers, and other personnel), and any related record to the accidents. These reports were reviewed by researchers, and incomplete reports excluded from the study (83 reports) leaving 500 reports ready for analysis.

Step 2: factor ranking

This step was to determine the importance of each studied factor for ASR. It included two stages: screening and ranking (18). Screening removed unimportant or problematic inputs, and ranking sorted the rest according to their importance. For ranking we used the IBM SPSS Modeler 14.2 (International Business Machines Corp. Armonk, NY, USA). Since the entry included a wide variety of data types such as continuous, nominal, flag, and ordinal data, we used Pearson's chi-squared test with the importance cut off point set to 0.95 (18).

Step 3: ASR modelling

In the final step, we used IBM SPSS v. 22.0 to investigate the relationship between all important factors and accident severity rate by means of multiple linear regression analysis. For this analysis, we first established the normality of ASR distribution using the Kolmogorov-Smirnov test. Then, depending on the result, we used Mann-Whitney U-test, Kruskal-Wallis test, or linear regression to analyse the relationship between ASR and the most important factors. Finally, the factors associated with ASR ($p<0.05$) were modelled using multiple linear regression.

RESULTS AND DISCUSSION

Table 1 shows overall mean and median lost working days and accident severity rates (ASR) and these values by percentiles. Our ASR findings are consistent with earlier reports (1-4), and the alarming risk of occupational accidents in construction industry calls for urgent action (2, 15).

Table 2 presents individual and organizational factors (IOFs) related to the injured construction workers. The mean age of the injured workers was below 30 years, average work experience below five years, over 80 % had no academic education, over 70 % were construction workers, and almost 70 % worked in construction at the time of the accident. These findings are not a surprise, as younger and inexperienced workers get to do more physically demanding and riskier jobs. However, they do point out that this is the population that requires most attention and safety and health training (10-11, 14).

Table 1 *Lost working days and accident severity rate from accident reports*

Statistics	lost working days	ASR
Mean	409.94	1515.9
Median	81.00	107.50
Standard Deviation (SD)	1495.713	10517.8
Percentiles		
10	34.00	28.6394
20	50.00	50.0000
25	55.00	57.2386
30	61.00	66.6667
40	75.00	86.8256
50	81.00	107.50
60	95.60	157.47
70	105.00	250.00
75	114.00	381.25
80	121.00	567.47
90	160.90	1298.6

Table 2 *Individual and organisational factors identified in accident reports*

Individual and organizational factors	Descriptive results
Age (years) (Mean ± SD)	29.18±7.67
Work experience (Mean± SD)	4.67±3.90
Number of workers (Mean± SD)	92.23±77.78
Education	
No-academic level	412 (82.4%)
Academic level	88 (17.6%)
Job Title	
Simple Construction Workers	362 (72.4%)
Technicians	124 (24.8%)
Drivers	14 (2.8%)
Activity type	
Construction Work	333 (66.6%)
Mechanical	39 (7.8%)
Installation	117 (23.4%)
Electricity	11 (2.2%)

Table 3 shows that only half of the injured workers received pre-employment safety and health training and only 22 % received periodic training after employment. Only 32 % of the workers were acquainted with housekeeping and only 21 % were using PPE. Of all workers, 26.4 % were satisfied with the duration and 14.2 % with the content of training they received. Even though this percentage does not reflect the ratio among workers that did receive any kind of training due to a fault in data gathering, we still get a pretty good idea of the inadequacy of the safety and health training programmes in construction industry.

Table 4 shows that a risk management system was established in only 18.4 % of the construction worksites. The rest of the factors confirm that there is so much left to be desired in risk management in Iranian construction industry.

The distribution analysis of lost working days and ASR showed that both indices were not normal, so we evaluated the relationship between ASR and the associated factors with the nonparametric tests (Table 5) and found that all factors were significantly associated with ASR ($p<0.05$).

Figure 1 shows the results of factor ranking using Pearson's chi-squared analysis (importance rate ≥0.95).

Multiple linear regression modelling (Table 6) has further filtered factors that were significantly associated with ASR (adjusted $R^2=0.812$, $p<0.05$) even after including all variables. ASR in construction, mechanical, and electrical activities was on average higher by 26.19, 14.70, and 6.20 than in installation activities, respectively.

Our regression model indicates that periodic training, knowledge about personal protective equipment, and content and duration of training significantly correlate with ASR. Awareness of workplace hazards is definitely one of the ways to reduce the risk of severe occupational accidents (19-21). Lack of and inadequate safety and health training for workers and project managers and poor safety climate and culture are already known as accident-associated factors (7), and our study calls for improvement in safety attitude and climate as a result of quality safety and health training (22). Our model has also singled out which training factors should the training address in particular: PPE

Table 3 *Safety and health training data related to the accidents reported by the 13 construction companies*

S&H training factors	Frequency (%)
Pre-employment training	240 (48.0%)
Periodic training	110 (22.0%)
Past accident training	88 (17.6%)
Knowledge of PPE	105 (21.0%)
Knowledge about housekeeping	16 (3.2%)
Satisfaction with training duration	132 (26.4%)*
Satisfaction with training content	71 (14.2%)*

Table 4 *Risk management factors identified in accident reports*

Risk management factors	Frequency (%)
Establishment system related to S&H	209 (41.8%)
Risk management system	92 (18.4%)
Accident investigation	83 (16.6%)
HAZID	82 (16.4%)
Periodic risk assessment	84 (16.6%)
PPE	51 (10.2%)
S&H checklists	270 (54.0%)
Hazard reporting system	48 (9.6%)
Tool box meeting (TBM)	53 (10.6%)
Housekeeping	29 (5.8%)
S&H audit and inspection	41 (8.2%)

S&H - safety and health

Table 5 *Relationship between ASR with IOFs, TFs and RMFs*

Factors		P-Value	Median (Interquartile ranges)	
Age		0.001†	-	
Work experience		0.001†	-	
Number of workers		0.001†	-	
Education		0.001‡	27.47 (22.00-37.60)	
Job Title	Simple Construction Workers	0.001††	93.58 (50.79-205.49)	
	Technicians		374.46 (108.06-1038.7)	
	Drivers		96.31 (65.91-550.14)	
Activity type	Construction Work	0.001††	81.52 (45.50-149.43)	
	Mechanical		666.67 (215.00-1185.7)	
	Installation		321.43 (119.45-881.31)	
	Electricity		850.00 (222.22-1575.0)	
			Yes	**No**
Pre-employment training			55.53 (32.79-80.96)	270.71 (135.71-844.44)
Periodic training		0.001‡	40.87 (26.32-66.04)	159.42 (85.15-558.90)
Past accident training		0.001‡	52.56 (27.00-73.86)	148.82 (76.26-525.45)
Knowledge of PPE		0.001‡	102.70 (41.30-646.67)	109.76 (64.10-351.22)
Housekeeping knowledge		0.001‡	16.73 (12.74-19.54)	110.67 (62.66-394.22)
Duration of training		0.001‡	52.58 (30.62-76.26)	274.60 (140.48-850.00)
Content of training		0.001‡	54.41 (32.21-78.57)	295.12 (140.48-850.00)
System related to S&H		0.001‡	52.35 (29.89-76.52)	229.17 (109.80-742.86)
Risk management system		0.001‡	28.66 (22.00-78.57)	146.90 (75.03-516.81)
Accident investigation		0.001‡	27.36 (21.14-41.66)	142.86 (75.00-496.67)
HAZID		0.001‡	25.74 (20.00-78.34)	133.10 (72.16-482.50)
Periodic risk assessment		0.001‡	27.43 (21.31-68.65)	142.86 (75.00-498.33)
PPE		0.001‡	23.68 (17.85-26.84)	121.25 (71.90-461.131)
S&H checklists		0.001‡	60.28 (36.26-87.47)	250.00 (122.72-985.23)
Reporting system		0.001‡	24.69 (17.83-41.48)	120.34 (66.66-455.75)
Tool Box Meeting		0.001‡	25.64 (19.80-34.66)	122.88 (73.00-475.00)
Housekeeping		0.001‡	24.39 (17.31-26.82)	117.50 (65.21-448.00)
S&H inspection and audit		0.001‡	26.00 (18.43-78.57)	117.78 (65.00-445.45)

† *Linear Regression*
‡ *Mann-Whitney U*
†† *Kruskal-Wallis H*

Table 6 *Results of construction accidents severity rate modelling*

Independent factors	B	t	$CI_{95\%}$	p-value†
IOFs				
Age	-18.37	-4.08	(-27.20)-(-9.54)	0.001
Work experience	-15.04	-2.87	(-25.30)-(-4.78)	0.004
Activity type				
Construction Work	26.19	2.73	(7.42)-(44.96)	0.006
Mechanical	14.70	3.70	(6.92)-(22.48)	0.001
Installation	(Reference)			
Electricity	6.20	4.36	(3.41)-(8.98)	0.001
Number of workers	2.54	4.55	(1.45)-(3.64)	0.001
Education				
No-academic level	14.46	0.962	(-16.25)-(47.17)	0.337
Academic level	(Reference)			
Job Title				
Simple Construction Workers	6.39	0.255	(-43.01)-(55.80)	0.799
Technicians	(Reference)			
Drivers	1.85	0.279	(-11.29)-(15.01)	0.781
TFs				
Periodic training	2.54	4.55	(1.44)-(3.64)	0.001
PPE knowledge	21.23	6.06	(14.36)-(28.10)	0.001
Satisfaction with training duration	15.26	3.83	(7.45)-(23.07)	0.001
Satisfaction with training content	17.92	2.54	(4.12)-(31.73)	0.011
Pre-employment	-3.31	-0.089	(-76.95)-(70.33)	0.929
Past accident	-0.350	-0.083	(-1.00)-(0.30)	0.292
Knowledge about housekeeping	-0.756	-0.206	(-8.00)-(6.49)	0.837
RMFs				
RMS	4.75	3.14	(1.78)-(7.72)	0.002
HAZID	16.52	2.75	(4.75)-(28.29)	0.006
Periodic risk assessment	22.91	2.18	(2.30)-(43.51)	0.029
Accident investigation	8.95	6.04	(6.04)-(11.86)	0.001
PPE	13.98	4.53	(7.93)-(20.04)	0.001
Housekeeping	33.94	3.86	(16.27)-(51.16)	0.001
System related to S&H	13.26	0.267	(-84.62)-(111.14)	0.789
S&H checklists	21.09	0.473	(-66.86)-(109.05)	0.637
Hazard reporting system	10.75	0.153	(-127.72)-(149.22)	0.878
Tool box meeting (TBM)	-1.43	-0.011	(-267.93)-(265.06)	0.992
S&H audit and inspection	-4.55	-0.047	(-196.73)-(187.61)	0.963

† *Multiple Linear Regressions; B - regression coefficient*
S&H - safety and health

knowledge (B=21.23) and training content (B=17.92), as they are highly associated with ASR.

Our regression model has also identified the most important factors associated with ASR in risk management: housekeeping (B=33.94) and periodic risk assessment (B=22.91). It has confirmed earlier findings by Haslam et al. (10) and Mitropoulos et al. (20). In fact, Haslam et al. found that poor housekeeping and other problems related to site layout contributed to about half of the construction accidents.

As for the other risk management factors, quite expectedly, high ASR is significantly associated with the failure to use PPE or to have the hazards identified, as well as with the failure to investigate the accident properly.

Haslam et al. (10) have shown earlier that deficiencies in risk management account for a high proportion of accidents in the construction industry. Ours and other studies (11-12, 23) clearly suggest that every construction company should have a well-designed construction risk management system (CRMS) in place to properly identify, analyse, control, and manage safety and health risks at their construction sites. A well-designed CRMS should include all important factors identified by our regression modelling to optimise the cost-benefit ratio and significantly decrease the frequency and severity of occupational accidents in construction industry.

One of the limitations of our study is the number of excluded accidents (83 of them), as it may lead to bias, but

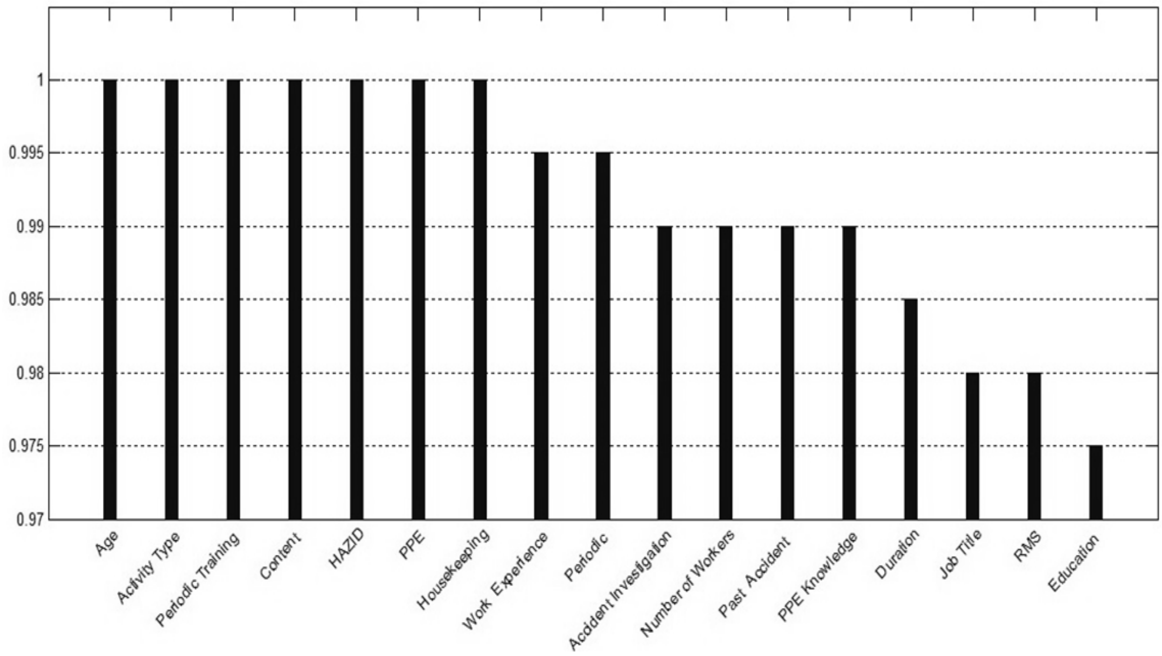

Figure 1 *Ranking of factors affecting accident severity rates in Iran's construction industry*

the remaining sample of 500 accidents provides an idea of the issue at hand.

One of the merits of our multiple regression approach over other methods is that we used two parallel methods to estimate and determine the key factors contributing to accident severity rate in construction industry. We hope that our study will help to improve the conditions at construction sites, especially in safety and health training and risk management.

Some questions such as determination of root causes and factors contributing to accident severity remain unanswered. Answering them will require a well-designed comprehensive study that will rely on root cause analysis.

Acknowledgements

We wish to sincerely thank all safety engineers of the 13 large construction industries for their invaluable and skilful assistance in data gathering at the studied construction sites.

REFERENCES

1. Im HJ, Kwon YJ, Kim SG, Kim YK, Ju YS, Lee HP. The characteristics of fatal occupational injuries in Korea's construction industry, 1997–2004. Safety Sci 2009;47:1159-62. doi: 10.1016/j.ssci.2008.11.008
2. Soltanzadeh AI. Mohammadfam I, Moghim Beygi A, Akbarzadeh M. Studying disabling occupational accidents in the construction industry during two years. J Occup Hyg Eng 2014;1:57-66.
3. Pellicer E, Carvajal GI, Rubio MC, CataláJ. A method to estimate occupational health and safety costs in construction projects. KSCE J Civil Eng 2014;18:1955-65. doi: 10.1007/s12205-014-0591-2
4. Häkkinen K, Niemelä V. Accident Sources and Prevention in the Construction Industry—Some Recent Developments in Finland. InIntegrated Occupational Safety and Health Management 2015 (pp. 17-24). Springer International Publishing.
5. Cameron I, Hare B, Davies R. Fatal and major construction accidents: A comparison between Scotland and the rest of Great Britain. Safety Sci 2008;46:692-708. doi: 10.1016/j.ssci.2007.06.007
6. Cheng C-W, Leu S-S, Lin C-C, Fan C. Characteristic analysis of occupational accidents at small construction enterprises. Safety Sci 2010;48:698-707. doi: 10.1016/j.ssci.2010.02.001
7. Pinto A, Nunes IL, Ribeiro RA. Occupational risk assessment in construction industry - Overview and reflection. Safety Sci 2011;49:616-24. doi: 10.1016/j.ssci.2011.01.003
8. Grant A, Hinze J. Construction worker fatalities related to trusses: An analysis of the OSHA fatality and catastrophic incident database. Safety Sci 2014;65:54-62. doi: 10.1016/j.ssci.2013.12.016
9. Suraji A, Duff AR, Peckitt SJ. Development of causal model of construction accident causation. Journal of construction engineering and management. 2001 Aug;127(4):337-44.
10. Haslam R, Hide SA, Gibb AG, Gyi DE, Pavitt T, Atkinson S, Duff AR. Contributing factors in construction accidents. Appl Ergon 2005;36:401-15. doi: 10.1016/j.apergo.2004.12.002
11. del Cano A. de la Cruz MP. Integrated methodology for project risk management. J Constr Eng Manage 2002;128:473-85. doi: 10.1061/(ASCE)0733-9364(2002)128:6(473)
12. Mills A. A systematic approach to risk management for construction. Structural Survey 2001;19:245-52. doi: 10.1108/02630800110412615
13. Mohamadfam I, Soleimani E, Ghasemi F, Zamanparvar A. Comparison of management oversight and risk tree and tripod-beta in excavation accident analysis. Jundishapur J Health Sci 2015;7(1):e23554. doi: 10.5812/jjhs.23554

14. Moradinazar M, Kurd N, Farhadi R, Amee V, Najafi F. Epidemiology of work-related injuries among construction workers of Ilam (Western Iran) during 2006-2009. Iran Red Crescent Med J 2013;15(10):e8011. doi: 10.5812/ircmj.8011
15. Cheng C-W, Applying data mining techniques to explore factors contributing to occupational injuries in Taiwan's construction industry. Accid Anal Prev 2012;48:214-22. doi: 10.1016/j.aap.2011.04.014
16. Cho K-M, Hong T-H, Hyun CT. Effect of project characteristics on project performance in construction projects based on structural equation model. Exp Syst Appl 2009;36:10461-70. doi:10.1016/j.eswa.2009.01.032
17. Sari M, Sevtap Selçuk A, Karpuz C. Stochastic modeling of accident risks associated with an underground coal mine in Turkey. Safety Sci 2009;47:78-87. doi: 10.1016/j.ssci.2007.12.004
18. Biesiada J. Duch W. Feature selection for high-dimensional data: a pearson redundancy based filter. In: Kurzynski M, editor. Computer recognition systems 2. Berlin Heidelberg: Springer-Verlag; 2007. p. 242-9.
19. Abdelhamid TS, Everett JG. Identifying root causes of construction accidents. J Constr Eng Manage 2000;126:52-60. doi: 10.1061/(ASCE)0733-9364(2000)126:1(52)
20. Mitropoulos P, Abdelhamid TS, Howell GA. Systems model of construction accident causation. J Constr Eng Manage 2005;131:816-25. doi: 10.1061/(ASCE)0733-9364(2005)131:7(816)
21. Fam IM, Nikoomaram H, Soltanian A. Comparative analysis of creative and classic training methods in health, safety and environment (HSE) participation improvement. J Loss Prevent Proc Ind 2012;25:250-3. doi: 10.1016/j.jlp.2011.11.003
22. Zhang RP, Li RYM. A Conceptual study of construction workers' safety performance from safety climate and social exchange perspectives. In: Li R, Li M, editors. Construction safety and waste management. Cham: Springer International Publishing AG; 2015. p. 123-37.
23. Ghasemi F, Mohammadfam I, Soltanian AR, Mahmoudi S, Zarei E. Surprising incentive: an instrument for promoting safety performance of construction employees. Safety Health Work 2015;6:227-32. doi: 10.1016/j.shaw.2015.02.006

Primjena regresijskog modela u analizi ključnih čimbenika koji pridonose težini nesreća u građevinskoj industriji u Iranu

Građevinska se industrija povezuje s najvišim rizikom od nesreća na radu i tjelesnih ozljeda u rasponu od blagih do vrlo teških. Cilj ovoga presječnog istraživanja bio je utvrditi čimbenike povezane s indeksom težine nesreća među najvećim građevinskim tvrtkama u Iranu na temelju podataka iz 500 izvještaja o nesrećama na radu prikupljanih od 2009. do 2013. Usto smo prikupili podatke o upravljanju rizikom za sigurnost i zdravlje radnika te o njihovu obrazovanju u tom pogledu. Podaci su analizirani Pearsonovim hi-kvadratnim testom i modelom višestruke regresije. Medijan indeksa težine nesreća (i interkvartilni raspon) iznosio je 107,50 (57,24-381,25). Na težinu nesreća najviše je utjecalo četrnaest od 24 ispitana čimbenika (p<0,05). Ovi rezultati mogu biti korisni u osmišljavanju i uspostavi obuhvatnih sustava upravljanja rizikom za sigurnost i zdravlje radnika kako bi se smanjio indeks težine nesreća na radu.

KLJUČNE RIJEČI: *analiza nesreća na radu; individualni čimbenici; organizacijski čimbenici; obrazovanje radnika, sigurnost na radu; upravljanje rizikom*