Original Article

Factors affecting occupational accidents in the construction industry (2009-2013)

Mohammadfam I, PhD[1], Soltanzadeh A, PhD[2*], Moghimbeigi A, PhD[3], Akbarzadeh M, PhD[4]

1- Associated Prof., Dept. of Occupational Hygiene Engineering, School of Public Health and Research Center for Health Sciences, Hamadan University of Medical Sciences, Hamadan, Iran. 2- PhD Candidate, Dept. of Occupational Hygiene Engineering, School of Public Health and Research Center for Health Sciences, Hamadan University of Medical Sciences, Hamadan, Iran. 3-Associated Prof., Dept. of Epidemiology & Biostatistics, Public Health Faculty, Hamadan University of Medical Sciences, Hamadan, Iran. 4-PhD Candidate, Dept. of Epidemiology & Biostatistics, Public Health Faculty, Hamadan University of Medical Sciences, Hamadan, Iran.

Abstract

Received: August 2015, **Accepted**: September 2015

Background: There is a high prevalence of occupational injuries due to accidents in construction industries which affect human health. Therefore, the exploration and analysis of contributing factors of such accidents can lead to their prevention and the reduction of their consequences. This study was conducted with the aim to identify factors related to occupational injuries and the severity of their consequences on large construction sites in Iran.

Materials & Methods: This study was a cross-sectional investigation on five-sequential-year accidents on large construction sites. Data included the information of 500 human injuries due to accidents. Data analysis was carried out using SPSS statistical software and statistical tests such as linear regression, independent sample t-test, and one-way ANOVA.

Results: The mean accident frequency rate and accident severity rate was 4.71 and 216.28, respectively. The average age and job experience of injured workers were 29.18 ± 7.67 and 4.67 ± 3.9 years, respectively, and had significant statistical difference with accident frequency rate and accident severity rate ($P < 0.05$). The association between accident indices and all factors related to accident type, equipment-related factors, unsafe condition and act, and accident nature was found to be significant ($P < 0.05$). Furthermore, the results showed that accident frequency rate and accident severity rate had a significant association with all factors related to health, safety, and the environment (HSE) training, housekeeping, and HSE control measures ($P < 0.05$).

Conclusions: The results indicate that the occurrence and severity of construction accidents were due to the combination of failures in a collection of different contributing factors including demographical and organizational factors, accident type, factors related to work conditions and equipment, unsafe actions and conditions, nature of accidents, HSE training and control measures, and accident time and place. Therefore, to prevent and reduce the rate of such accidents, all these factors should be regarded.

Keywords: Occupational Accidents, Construction Industry, Accident, Iran

Introduction

The construction industry and its related projects and sites, where construction activities are performed, are the most hazardous places with high risk of accidents, human injuries, and damages. Occupational accidents in the construction industry not only influence personnel safety and health, but also have negative impact on the economy (1, 2). Some studies indicate that more attention should be paid to safety and health because indeed the amount of compensation for workers injuries and cure expenses are increasing (3-5). In fact, it has been shown in the study by Dong that the rate and cost of injuries in the construction industry is higher than the average rate of occupational accidents and injuries of all industries (3).

[*] **Corresponding author:** Ahmad Soltanzadeh, Dept. of Occupational Hygiene Engineering, School of Public Health and Research Center for Health Sciences, Hamadan University of Medical Sciences, Hamadan, Iran.
Email: Soltanzadeh.ahmad@gmail.com

In addition, Silverstein et al. estimated that the rate of cure and compensation expenses in the construction industry is 4 times that of other industries (6). Since the construction industry is an important employment source in every country, the occurrence of incidents, accidents, and consequently, occupational damages can influence a large number of the workforce and population in every society. Therefore, the consideration of safety and health problems is essential. In the construction industry, workers perform various kinds of activities each of which has its own dangers. One of the most important facts about safety issues in the construction industry is that all working-class, including workers, technicians, foremen, and supervisors who are responsible for project management and control, are exposed to work hazards either directly or indirectly (7, 8).

Some researchers have found various factors of safety performance in the construction industry which can be used for the occupational accidents analysis and assessment of the construction industry (1, 9-11). Continuous change in construction projects, exposure to many materials, poor working conditions, non-continuous employment and cross-seasonal work, and exposure to pollutants (noise, vibration, dust, and direct exposure to the outside weather) are the important parameters which make the construction industry a high-risk environment of health and safety issues all around the world (1, 11- 12). Moreover, the risk of occupational accidents (including falling, throwing objects, collision and crash, chemicals, manual material handling, and abrasion with equipment) naturally exists in all construction projects. Therefore, construction projects may fail to fulfill their goals such as completion of the project in the estimated time and budget, project quality, and expected extent of accidents and damages (9, 11, 13- 14).

Identifying factors and causes of accidents is an essential part of accident analysis and a way of preventing them. As a result, researchers have tried hard to explain and analyze different kinds of accidents and factors (10, 15). Therefore, this study was implemented with the purpose of identifying factors of occupational injuries due to accidents and identification of hazards and health, safety, and the environment (HSE) risks in 13 large construction industry sites in Iran during 5 years (2009-2013).

Materials and Methods

In this analytical cross-sectional study, accident investigation was performed in different construction sites during the years 2009 to 2013. Accident cases in this study were chosen using a census and all accidents which caused human injuries were analyzed.

Accident data collection: In the present study, data were gathered through accident registration forms available in the construction industries, a tailor-made checklist, and interviews with injured workers, witnesses, and supervisors who were involved in the accidents. All recorded reports of different occupational accidents on construction sites were gathered, then, accident investigation was performed on the basis of a predefined pattern. Subsequently, additional data about the accidents were gathered using interviews or checklists. The analyzed data in this study included:

1) Construction project features: job title or types of work involved, construction activity, and number of workers
2) Personal and demographical features of injured personnel: age, job experience, and education
3) Details of accident time and place: accident place, and accident time including time of day, month, and year
4) Work conditions: failure in machinery, equipment, hand tools, electricity, and chemicals.
5) Unsafe acts and conditions: predisposing conditions, human errors, and hazardous acts.

6) Accident type: falling, throwing objects, slipping, crash, electrocution, and chemicals
7) Accident nature: death, amputation, burning, fracturing, bruising, cutting
8) HSE training process items such as awareness of hazards
9) HSE control measures and housekeeping: personal protective equipment (PPE), workers' knowledge about housekeeping and its role in preventing and reducing accidents and their consequences.

It should be mentioned that after data collection, researchers reviewed the data precisely; therefore, accidents on which information was incomplete were excluded from the study. Finally, 500 accidents were qualified for investigation.

Accident frequency and severity rates: Accident frequency rate (AFR) and accident severity rate (ASR) can be mentioned as quantity and monitoring indices of accident analysis. Moreover, these indices are used to assess HSE performance and safety problems in the industry. AFR and ASR were calculated based on the frequency and work days lost due to the accidents. According to the Occupational Safety and Health Administration (OSHA), accident indices can be calculated as follow (16, 17):

$$\mathrm{AFR} = \frac{\text{total number of accidents} \times 200000}{\text{total number of hours worked}}$$

$$\mathrm{ASR} = \frac{\text{total number of dayslost} \times 200000}{\text{total number of hours worked}}$$

Data analysis: In this study, data analysis was conducted using IBM SPSS Statistics (version 22, IBM Corp., Armonk, NY, USA) and the level of significance was set at P = 0.05. Accident analysis was carried out by means of independent sample t-test, linear regression, and one-way ANOVA. To investigate the relation of accident indices with quantity factors such as age and job experience, linear regression was used; however, independent sample t-test and one-way ANOVA were used to investigate accident indices with respect to quality factors.

Table 1: Descriptive and analytical analysis of demographic and organizational factors with accident indices

Factors	Mean ± SD/ Frequency (%)	P-value AFR	P-value ASR
Age (year)	29.18 ± 7.67	0.001†	0.001†
Job experience (year)	4.67 ± 3.90	0.032†	0.011†
Education			
Below diploma	203 (40.6)	0.021††	0.003††
Diploma	209 (41.8)		
Academic degree	88 (17.6)		
Job title			
Construction workers	362 (72.4)	0.025††	0.014††
Technicians	124 (24.8)		
Drivers	14 (2.8)		
Activity type			
Construction work	333 (66.6)	0.048††	0.034††
Mechanical	39 (7.8)		
Installation	117 (23.4)		
Electricity	11 (2.2)		

AFR: Accident frequency rate; ASR: Accident severity rate
† Linear regression
†† One-way ANOVA
‡ Independent sample t-test

Results

As was mentioned, 500 accidents which had led to human injuries were investigated. Initial accident analysis results indicated that 739 workers had been injured through the studied accidents. Additionally, the results of accident indicators analysis showed that the mean of AFR and ASR were 4.71 and 216.28, respectively.

Table 1 illustrates the results of descriptive analysis of demographic and organizational factors and also their relation with accident indices. As the results show, the average age and job experience of injured workers were 29.18 ± 7.67 and 4.67 ± 3.90 years, respectively, and only one-fifth (17.6%) of them have academic education. Furthermore, over 70% of injured personnel were simple workers and about 25% of them were technicians. Additionally, it can be observed that about 25% of accidents have occurred during installation works while the other 70% have occurred during construction tasks. Comparing individual characteristics of injured personnel like age, job experience, and education showed that there is a significant statistical difference with respect to accident indices ($P < 0.05$). In addition to the relation between organizational factors, job type and activities which lead to human accidents and accident indices were reported as significant ($P< 0.05$).

Table 2: Descriptive and analytical analysis of factors contributing to accidents

Factors	Frequency (%)	P-value	
		AFR	ASR
Accident type factors			
Fall	113 (22.6)	0.005‡	0.013‡
Throwing objects	113 (22.6)	0.005‡	0.002‡
Slipping	108 (21.6)	0.009‡	0.002‡
Collision and crash	86 (17.2)	0.014‡	0.002‡
Abrasion	76 (15.2)	0.018‡	0.027‡
Electrical shock	48 (9.6)	0.033‡	0.001‡
Chemicals	36 (7.2)	0.041‡	0.002‡
Manual handling	74 (14.8)	0.020‡	0.004‡
Equipment-related factors			
Machines	59 (11.8)	0.032‡	0.040‡
Equipment	105 (21.0)	0.001‡	0.004‡
Power	45 (9.0)	0.039‡	0.002‡
Hand tools	39 (7.8)	0.014‡	0.024‡
Chemicals	36 (7.2)	0.048‡	0.002‡
Unsafe conditions and actions			
Unsafe conditions	161 (32.2)	0.001‡	0.004‡
Unsafe actions	311 (62.2)	0.001‡	0.003‡
Nature of accidents			
Death	19 (3.8)	0.172‡	0.005‡
Amputation	16 (3.2)	0.234‡	0.009‡
Burn	59 (11.8)	0.048‡	0.001‡
Fracture	165 (33.0)	0.031‡	0.002‡
Hernia	78 (15.6)	0.044‡	0.002‡
Strains	165 (33.0)	0.031‡	0.001‡
Crash	40 (8.0)	0.053‡	0.004‡
Cuts and perforation	140 (28.0)	0.036‡	0.001‡

AFR: Accident frequency rate; ASR: Accident severity rate

‡ Independent sample t-test and linear regression

Table 2 contains the results of the factors analysis of accidents. The results showed that the rate of factors such as falling and throwing objects was high (22.6%). Secondly, the highest rate of accidents (21.6%) was due to slipping. Furthermore, statistical analysis showed that all of these factors have significant relationships with AFR and ASR ($P< 0.050$). Moreover, the results of equipment and work condition analysis showed that unsafe actions, unsafe conditions, and equipment and machinery have the most important role in occupational accidents in the construction industry ($P < 0.05$). Other factors such as failure in electric current related activity, working with unsafe and inappropriate hand tools, and chemicals were also studied, but the prevalence of each was less than 10%. Moreover, accident nature analysis results indicated that the percentage of accidents which lead to death and amputation were 3.8% and 3.2%, respectively. Furthermore, most injuries were due to bruising and fracturing (each one 33%), cuts and punctures (28%), and hernia (15.6%). It was also noticeable that 11.8% of all injuries were due to burning accidents. The relation between ASR and all factors related to accident nature was found to be significant ($P<0.05$). These results showed that some factors of accident nature including death, amputation, and crash do not have a significant relation with AFR ($P> 0.05$).

Table 3: Descriptive and analytical analysis of HSE training and control factors related to construction accidents

Factors	Frequency (%)	P-value	
		AFR	**ASR**
HSE training factors			
Pre-employment training	240 (48.0)	0.004‡	0.040‡
Periodic training	110 (22.0)	0.009‡	0.004‡
Training after accident	88 (17.6)	0.017‡	0.002‡
Duration of training	132 (26.4)	0.006††	0.028††
Content of the training	71 (14.2)	0.029††	0.025††
Housekeeping			
Housekeeping knowledge	16 (3.2)	0.001‡	0.002‡
Housekeeping establishment	29 (5.8)	0.001‡	0.002‡
HSE control measures			
Awareness of PPE	105 (21.0)	0.001‡	0.024‡
control measures such as PPE	51 (10.2)	0.031‡	0.002‡
HSE inspection and audit	41 (8.2)	0.001‡	0.003‡
Toolbox meeting	53 (10.6)	0.030‡	0.006‡

AFR: Accident frequency rate; ASR: Accident severity rate
‡ Independent sample t-test and linear regression
†† One-way ANOVA

Results of table 3 show that the precentage of injuries among those who had received HSE training before employment, during employment, and after the accident was 48%, 22%, and 17.6%, respectively. Additionally, the results of duration and training course content indicated that there was 26.4% and 14.2% satisfaction with these factors, respectively. The analysis of housekeeping factor indicated that housekeeping had been established only in 5.8% of cases and 3.2% of injured personnel had knowledge about the role of housekeeping in prevention and reduction of accidents and their consequences. In addition, analysis of control measures proved that only 21% of injured workers had been trained on how to use PPE and such equipment were used by 10.2% of workers. The percentages of control measure components including inspection and audit and toolbox meeting (TBM) implementation were reported to be 8.2% and 10.6%, respectively.

Additionally, the results showed that all factors related to HSE training, housekeeping, and HSE control measures had significant relations with AFR and ASR (P < 0.05).

Accident time and place and their relation to accident indices showed that a higher number of occupational accidents occurred in tropical climates than other climates. Moreover, accident analysis in terms of accident time showed that most accidents took place at the beginning and end of work. Investigation of seasonal work indicated that most accidents occur in the first two seasons of the year (spring and summer). Table 4 shows that there is a statistically significant relation between accident time and place and the indices of construction occupational accidents (P < 0.05).

Table 4: Analysis of time and place factors of accidents

Factors	Frequency (%)	P-value	
		AFR	**ASR**
Place factors			
Hot areas	249 (49.8)	0.005††	0.042††
Deserts	98 (19.6)		
Cold areas	153 (30.6)		
Time factors			
Day-time			
Morning (7-10)	179 (35.8)	0.017††	0.009††
Noon (11-14)	116 (23.2)		
Afternoon (15-18)	205 (41.0)		
Season			
Spring	119 (23.8)		
Summer	199 (39.8)	0.006††	0.001††
Fall	121 (24.2)		
Winter	61 (12.2)		

AFR: Accident frequency rate; ASR: Accident severity rate
†† One-way ANOVA and linear regression

Discussion

The findings of this study showed that construction accidents were a combination of different factors. These factors consisted of individual and organizational factors, accident type, equipment and work conditions, unsafe actions, accident nature, accident time and place, HSE training factors, and a collection of HSE controlling measures like PPE use, housekeeping, and applying TBM programs. In other words, construction accidents were due to a failure in the interaction between workers and work place, materials, and equipment involved (13-14).

The findings of this study and some other studies have shown that construction industry and its related sites are a dangerous and high risk environment the consequences of which can lead to adverse and catastrophic accidents (18-19). Therefore, identifying and analyzing these factors can assist in the identification of hazards and risks of projects, and their analysis and management. It can also reduce the rate of accidents and occupational damages on construction sites (5, 7, 9, 11, 20).

AFR and ASR are part of the reactive and effective indices in the construction analysis of accidents. While AFR was acceptable in this study, ASR was high (21).

According to individual and demographic features and organizational factors of injured workers, the injured personnel were young and had low work experience. Moreover, most of the injured personnel were construction workers and technicians, who are exposed to dangers in a direct or indirect way (7, 11). Haslam et al. showed that some of the important and effective factors of occupational injuries are related to the workers or work-team (70%) (14). The important role of individual and organizational variables in the construction industry, compared with other industries, is due to workers themselves being responsible for their own and the organization's safety. Thus, the role of these factors in each job and activity involved was significant. This finding was consistent with that of other studies (7, 11, 14)

As accident type analysis showed, almost all kinds of accidents possible (falling, throwing objects, slipping, collision and crash, abrasion and loading) have occurred. According to statistical reports, the highest number of injuries was due to falling and throwing objects, and thus, they have an important role in accident occurrence. Furthermore, the results of equipment and work condition analysis have proved that unsafe actions, conditions, and equipment and machinery have the most important role in occupational accidents in the construction industry. Thus, statistical analyses have proved that there is a significant relation between accident indices and all factors (accident type, equipment and work conditions, and unsafe actions and conditions).

Furthermore, the relation between ASR and all factors related to accident nature has been found to be significant ($P < 0.05$). These results showed that some factors of accident nature do not have a significant relation with AFR. These factors are death, amputation, and crash. Grant and Hinze reported that 68% of accidents were the result of falling (20). Work-related conditions and equipment factor analysis indicated that unsafe actions, unsafe conditions, equipment and machinery, failure in electric current related activity, using unsafe and inappropriate hand tools, and chemicals have the most important role in occupational accidents on construction sites. This finding was in line with the findings of other studies (22).

It should be noted that analytical results of HSE training factor, housekeeping, and HSE control measures, and also their relation with accident indices including AFR and ASR in construction industries revealed that the implementation rate of these factors was very low on construction sites (Table 3). In addition, the HSE training factors had a decreasing pattern. Moreover, statistical analyses showed that there was a significant relation between accident indices and all factors related to HSE training, housekeeping, and HSE control measures. Findings of the studies by Pinto (7) and Sertyesilisik (10) indicated that another factor which affects accident occurrence and its consequences is the training process and its related factors. Although the construction industry is a dangerous environment, HSE training and its correct application can help reduce the frequency and severity of occupational accidents on construction sites. In addition, following designed steps such as pre-employment training, periodic training, and training after an accident, housekeeping, and PPE training can lead to safe actions and conditions on construction sites (7, 11, 22).

Haslam et al. revealed that inadequate and lack of use of risk control equipment like PPE (56%) and lack of or failure in applying risk control measures (84%) are significant contributory factors of construction accidents (14).

Hence, it was found that factors such as housekeeping and performing actions like TBM in the construction industry are important in the prevention of accidents and reduction of their consequences. This finding was consistent with that of other studies (18). Poor housekeeping has been found to be an effective issue and factor in half of the construction accidents (14, 18).

As a result of the investigation of many factors and their roles in construction accidents in this study, it was observed that construction accidents were due to failure in the interaction between workers and workplace, materials, and equipment. Therefore, for the causal analysis of these accidents and investigation of their connections further studies are required.

Conclusion

The findings of the present study revealed that the frequency and severity of occupational accidents in the construction industries were due to the combination of a variety of failures. These failures included demographic and organizational factors, accident type, factors related to work conditions and equipment, unsafe actions and conditions, nature of accidents, HSE training and control measures, and accident time and place. Therefore, to prevent such accidents and reduce their severity, all of the abovementioned factors should be considered precisely in all HSE programs.

Acknowledgments

The authors wish to sincerely thank Mr. Shahram Mahmoudi, HSE engineer, for his invaluable and skillful assistance in data gathering. The present study was sponsored by Hamadan University of Medical Sciences, Iran.

Conflict of interest: None declared.

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. Saf Sci 2009; 47(8):1159-62.
2. Soltanzadeh A, Mohammadfam I, Moghimbeygi A, Akbarzadeh M. Studying Disabling Occupational Accidents in the Construction Industry During Two Years. Journal of Occupational Hygiene Engineering 2014; 1(2):57-66.
3. Dong X, Ringen K, Men Y, Fujimoto A. Medical costs and sources of payment for work-related injuries among Hispanic construction workers. J Occup Environ Med 2007; 49(12):1367-75.
4. Hinze J, Devenport JN, Giang G. Analysis of construction worker injuries that do not result in lost time. J Constr Eng Manag 2006; 132(3):321-6.
5. Lee S, Halpin DW, Chang H. Quantifying effects of accidents by fuzzy-logic-and simulation-based analysis. Canadian Journal of Civil Engineering 2006; 33(3):219-26.
6. Silverstein B, Welp E, Nelson N, Kalat J. Claims incidence of work-related disorders of the upper extremities: Washington state, 1987 through 1995. Am J Public Health 1998; 88(12):1827-33.
7. Pinto A, Nunes IL, Ribeiro RA. Occupational risk assessment in construction industry–Overview and reflection. Saf Sci 2011; 49(5):616-24.
8. Baradan S, Usmen M. Comparative injury and fatality risk analysis of building trades. J Constr Eng Manag 2006; 132(5):533-9.
9. Tam CM, Zeng SX, Deng ZD. Identifying elements of poor construction safety management in China. Saf Sci 2004; 42(7):569-86.
10. Sertyesilisik B, Tunstall A, McLouglin J. An investigation of lifting operations on UK construction sites. Saf Sci 2010; 48(1):72-9.
11. Cheng CW, Leu SS, Lin CC, Fan C. Characteristic analysis of occupational accidents at small construction enterprises. Saf Sci 2010; 48(6):698-707.
12. Cameron I, Hare B, Davies R. Fatal and major construction accidents: A comparison between Scotland and the rest of Great Britain. Saf Sci 2008; 46(4):692-708.
13. Lopez Arquillos A, Pubio Romero JC, Gibb A. Analysis of construction accidents in Spain, 2003-2008. J Safety Res 2012; 43(5-6):381-8.
14. Haslam RA, Hide SA, Gibb AG, Gyi DE, Pavitt T, Atkinson S, et al. Contributing factors in construction accidents. Appl Ergon 2005; 36(4):401-15.
15. Hoyos CG, Zimolong BM. Occupational safety and accident prevention: behavioral strategies and methods. NewYork: Elsevier; 1988.
16. Occupational Safety & Health Administration (OSHA). Safety & health managment system etool [Internet]. Washington: U.S. Department of Labor, Occupational Safety & Health Administration; 2012 [cited 2012]. Available from: https://www.osha.gov/SLTC/etools/safetyhealth/
17. Sari M, Selcuk AS, Karpuz C, Duzgun HS. Stochastic modeling of accident risks associated with an underground coal mine in Turkey. Saf sci 2009; 47(1):78-87.
18. Perlman A, Sacks R, Barak R. Hazard recognition and risk perception in construction. Saf Sci 2014; 64(4):22-31.
19. 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.
20. Grant A, Hinze J. Construction worker fatalities related to trusses: An analysis of the OSHA fatality and catastrophic incident database. Saf Sci 2014; 65:54-62.
21. Ali-Lin Teo E, Feng Y. The moderated effect of safety investment on safety performance for building projects. International Journal of Construction Management 2010; 10(3):45-61.
22. Mitropoulos P, Abdelhamid T, Howell G. Systems model of construction accident causation. J Constr Eng Manag 2005; 131(7):816-25.