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MULTIDISCIPLINAR ASPECTS OF OCCUPATIONAL ACCIDENTS AND INJURIES

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Jovica Jovanović, Mirjana Aranđelović, Milan Jovanović

Institute of Occupational Health Niš, Faculty of Medicine, University of Niš
Braće Taskovića 50, 18 000 Niš, E mail: joca@medfak.ni.ac.yu

Abstract. *Occupational accidents, work related injuries and fatalities resulting from multiple causes, affect different segments of the working population, and occur in a myriad of occupations and industrial settings. Multiple factors and risks contribute to traumatic injuries, such as hazardous exposures, workplace and process design, work organization and environment, economics, and other social factors. With such a diversity of theories, it will not be difficult to understand that there does not exist one single theory that is considered right or correct and is universally accepted. These theories are nonetheless necessary, but not sufficient, for developing a frame of reference for understanding accident occurrences. Prevention strategies are also varied, and multiple strategies may be applicable to many settings, including engineering controls, protective equipment and technologies, management commitment to and investment in safety, regulatory controls, and education and training. Research needs are thus broad, and the development and application of interventions involve many disciplines and organizations.*

Key Words: *Occupational Accidents, Work Related Injury, Occupational Hazards, Workers, Industry*

BACKGROUND

Occupational accident is an unexpected and unplanned occurrence, including acts of violence, arising out of or in connection with work which results in one or more workers incurring a personal, disease or death. As occupational accidents are to be considered travel, transport or road traffic accidents in which workers are injured and which arise out of or in the course of work, i.e. while engaged in an economic activity, or at work, or carrying on the business of the employer. As occupational accidents are to be considered accidents occurring on the habitual route, in either direction, between the place of work or work related training and the workers principal or secondary residence, the place where

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the worker usually takes his or her meals, or the place where he or she usually receives his or her remuneration, which results in death or personal injury.

An occupational injury is any personal injury, physical damage to body tissues or death from an occupational accident. Occupational injuries are responsible for more lost time from work, productivity, and working years of life than any other health conditions. Injuries are the leading cause of morbidity and mortality among the workers. Thousands of people are killed annually in industrial accidents, and the number of disabling injuries is also a staggering figure. Many workers suffered job related injuries that resulted in lost work time, medical treatment, loss of consciousness, restriction of work or motion, or transfer to another job. Today injuries continue to claim the lives, damage the physical and psychological well-being and consume the resources of workers and their families. The overall human, social, and financial toll of traumatic occupational injury is enormous, rivaling the burden imposed by such health threats as cancer and cardiovascular disease.

CONSEQUENCES

Each year, occupational accidents result in staggering costs in terms of loss of life, pain and suffering, lost wages for the injured worker, damage to production facilities and equipment, and loss production opportunity. The direct cost (lost wages, medical and rehabilitation payments, insurance administrative costs, property loses, production loses) plus indirect costs (cost associated with pain and suffering by workers and family members) of occupational injuries were estimated to be about $ 30 billion annually (1). These figures underestimate the true count and cost of all work injuries, however, because of underreporting of non acute injuries by many industrial record keeping systems. Outcome studies have addressed time lost from work and cost of compensation, health, functional and family outcomes. Work related upper extremity cumulative trauma disorders result in persisting symptoms and difficulty in performing simple activities of daily living, impacting home life even more than work, job loss, symptoms of depression and family disruption were common (2).

Ulnar post traumatic aneurysms of the hand and shingles as a consequences of occupational injury have been previously reported in the medical literature (3,4). Occupational accidents involving sharp instruments (needles, scalpels, scissors) are important because of their capacity of transmit through the blood serious pathogenic agents. At least 20 pathogenic microorganisms can be transmitted via a needle stick injury (5). Post traumatic stress disorder, mood disorders, changes of emotional state, cognitive and psychosocial disabilities are the most common consequences of occupational accidents (6,7). Occupational accidents are a major source of ocular trauma, which is represented by a wide spectrum of injuries with substantial morbidity and economic costs (8). Of the 913 non fatal injuries, 41% resulted in an employee missing work and incurred a total of 22730 lost workdays, an average of 61 days per lost workday incident (9). Musculoskeletal injuries are the predominant form of reported non fatal occupational injuries (10).

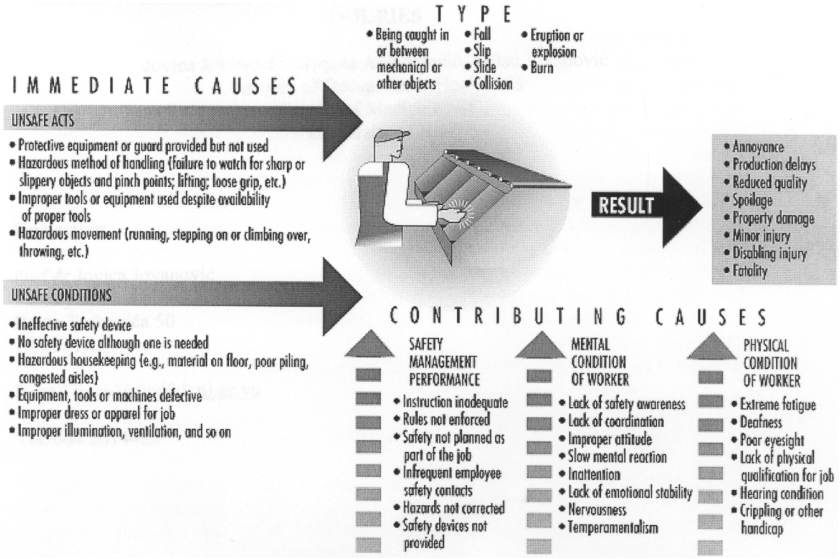

Fig. 1. Structure of accidents

EPIDEMIOLOGY

Data on occupational accidents are not available from all countries in the world. The average estimated fatal occupational accident rate in whole world was 14.0 per 100,000 workers (11). The rates are different for individual countries and regions and for separate branches of economic activity. The European Union rate was 5.89 per 100,000 workers. The highest rates (23.1 per 100,000 workers) are found in Asia. The rapidly industrializing countries such as the Republic Korea, Thailand, and Indonesia have reported high fatal accident frequency rates (11). United States annual fatality rate was 3.2 per 100,000 workers (12).

Certain industries such as mining agriculture, forestry and construction had the high rates of fatal accidents (13,14). While non fatal accidents declined during last six decades the construction, agriculture, manufacturing, transportation, fishing industry and mining sectors continue to experience high rates of disabling injuries (12,15). Agriculture is one of the most hazardous industries. Risk of agricultural injuries is approximately 5-10/100 persons per year, but is higher in certain risk groups, such as males and cattle workers. Falls, machinery and animals are among the most the most common causes (16). Unique features of agricultural workplace and exposed population, wide range of activities, hazards, dispersed workplaces in agriculture, a seasonal hired workforce that often has brief tenure, poor skills combine to increase risk for occupational injuries.

Examples of overt trauma and commonly affected occupational groups given in literature (17,18,19) are shown on Table 1. Fractures, bruises, lacerations, contusions, penetration by foreign bodies and sprains or strains are the most frequent injury types. Fingers, hands, eyes, feet, arms and legs are most often affected (17, 20). Among the health care workers most reported incidents occurred on hospital wards. The most com-

mon incidents were needle stick injuries, and 35% occurred when the needle was re-capped. Medical laboratory technicians and nurses reported significantly more mucocutaneus incidents than other professionals. In 10% of the incidents, the patient had a known blood borne infection. The majority of accidents occurred in operating theatres, and connection with anesthesia (21).

Table 1. Examples of overt trauma and commonly affected occupational groups

Cause	Injury type	Affected occupations
Mechanical energy	Lacerations	Sheet metal workers, butchers, press operators, sawyers, fabric cutters
	Fractures	Materials handlers, miners, construction workers
	Contusions	Materials handlers, any workers exposed to low energy impacts
	Amputations	Press operators, butchers, machine operators
	Crushing injuries	Materials handlers, press operators, construction workers, rubber workers
	Eye injuries	Miners, grinders, saw mill operators, machine shop employees
	Strains / Sprains	Materials handlers, miners, baggage handlers, mail handlers, construction workers
Thermal energy	Burns	Foundry workers, smelter workers, welders, glass workers, laundry workers
	Heat strain	Firefighters, steel workers, smelter workers
	Cold strain	Utility workers, lumberjacks, butchers
Chemical energy	Burns	Masons, process workers, hazardous waste workers
	Asphyxiation, Acute toxicity	Firefighters, confined space workers, hazardous waste workers
Electrical energy	Electrocution, shocks, burns	Utility workers, construction workers, electricians, users of electric tools or machines
Nuclear energy	Radiation burns	Hospital workers, industrial radiographers, nuclear workers

More injuries occurred in Monday and Thursdays, between 9 am to 10 am (19). These peaks in incident frequency for a particular time of day may simply reflect a higher number of persons working at those times rather than changing incidence during the day. The peaks in incident times could also be the result of different operations being performed at different times of the day, or might be due to changes in worker behavior.

The highest injury incidence rates are among the younger workers (12, 20, 22, 23, 24, 25). It has been well documented that age and accident rates are negatively related (probably because older workers are more experienced on the job and have greater job knowledge, patience, and skills than younger counterparts. When injuries do occur, older workers are usually more severely hurt, and fatalities occur more frequently among older workers. Some of the possible reasons why younger workers may be at increased of work related injury are limited job knowledge, training, and skills, and perhaps less sense of responsibility. These factors all point to the importance of safety attitudes in performing safety at work. Older workers are more satisfied with job and more likely to asses general housekeeping and checking of safety equipment. Older workers could be more knowledgeable and experienced display more positive attitudes to safety, and possibly

more committed to work than younger workers. Older workers are quite capable of learning safety regulations and safety system of work, and are willing to comply with safety regulations. Perhaps it is attributable to the fact that job knowledge structures increase with age and compensate for declines in ability.

The risk of occupational related traumatic injury is inversely related to worker age and educational level (17).

Accident Causation

Occupational accidents, work related injuries and fatalities result from multiple causes. Many traditional theories about the causes of occupational accidents focus on the worker. Many attempts have been made to develop a prediction theory of accident causation, but so far none has been universally accepted. Researchers from different fields of science and engineering have been trying to develop a theory of accident causation which will help to identify, isolate and ultimately remove the factors that contribute to or cause accidents.

ACCIDENT CAUSATION THEORIES

The Domino Theory

According to the domino theory, 88% of all accidents are caused by unsafe acts of people, 10% by unsafe actions and 2% by "acts of God". It proposed a "five-factor accident sequence" in which each factor would actuate the next step in the manner of toppling dominoes lined up in a row. The sequence of accident factors is as follows:

1. ancestry and social environment
2. worker's fault
3. unsafe act together with mechanical and physical hazard
4. accident
5. damage or injury

In the same way that the removal of a single domino in the row would interrupt the sequence of toppling. Removal of one of the factors would prevent the accident and resultant injury, with the key domino to be removed from the sequence being number 3. Although the author provided no data for his theory, it nonetheless represents a useful point to start discussion and a foundation for future research.

Multiple Causation Theory

The multiple causation theory is an outgrowth of the domino theory, but it postulates that for a single accident there may be many contributory factors, causes and sub-causes, and that certain combinations of these give rise to accidents. According to this theory, the contributory factors can be grouped into the following two categories:

1. Behavioral factors, which include factors pertaining to the worker, such as improper attitude, lack of knowledge, lack of skills and inadequate physical and mental condition.
2. Environmental factors, which include improper guarding of other hazardous work elements and degradation of equipment through use and unsafe procedures.

The major contribution of this theory is to bring out the fact that rarely, if ever, is an accident the result of a single cause or act.

The Pure Chance Theory

According to the pure chance theory, every one of any given set of workers has an equal chance of being involved in an accident. It further implies that there is no single discernible pattern of events that leads to an accident. In this theory, all accidents are treated as acts of God, and it is held that there exist no interventions to prevent them.

The Biased Liability Theory

The biased liability theory is based on the view that once a worker is involved in an accident, the chances of the same worker becoming involved in future accidents either increase or decrease as compared to the rest of workers. This theory contributes very little, if anything at all, towards developing preventive actions for avoiding accidents.

The Accident Proneness Theory

The accident proneness theory maintains that within a given set of workers, there exists a subset of workers who are more liable to be involved in accidents. Researchers have not been able to prove this theory conclusively because most of the research work has been poorly conducted and most of the findings are contradictory and inconclusive. This theory is not generally accepted. It is felt that if indeed this theory is supported by any empirical evidence at all, it probably accounts for only a very low proportion of accidents without any statistical significance.

The Energy Transfer Theory

Those who accept the energy transfer theory put forward the claim that a worker incurs injury or equipment suffers damage through a change of energy, and that for every change of energy there is a source, a path and a receiver. This theory is useful for determining injury causation and evaluating energy hazards and control methodology. Strategies can be developed which are either preventive, limiting or ameliorating with respect to the energy transfer. Control of energy transfer at the source can be achieved by the elimination of the source, changes made to the design or specification of elements of the work station, preventive maintenance. The path of energy transfer can be modified by enclosure of the path, installation of barriers, installation of absorbers, positioning of isolators. The receiver of energy transfer can be assisted by limitation of exposure and use of personal protective equipment.

The "Symptoms *Versus* Causes" Theory

The "symptoms *versus* causes" theory is not so much a theory as an admonition to be heeded if accident causation is to be understood. Usually, when investigating accidents, we tend to fasten upon the obvious causes of the accident to the neglect of the root causes. Unsafe acts and unsafe conditions are the symptoms, the proximate causes, and not the root causes of the accident.

STRUCTURE OF ACCIDENTS

The belief that accidents are caused and can be prevented makes it imperative for us to study those factors which are likely to favor the occurrence of accidents. By studying such factors, the root causes of accidents can be isolated and necessary steps can be taken to prevent the recurrence of the accidents. These root causes of accidents can be grouped as "immediate" and "contributing". The immediate causes are unsafe acts of the worker and unsafe working conditions. The contributing causes could be management-related factors, the environment and the physical and mental condition of the worker. A combination of causes must converge in order to result in an accident (26,27,28,29)(Figure 1).

Human error is often cited as cause of occupational mishaps and occupational accidents. The new view in ergonomics today does not see human errors as a cause, but as a symptom, as an effect of failure deeper inside the systems in which people work. Adherents of the new view use terms like system accident to attest to the multitude of factors, all necessary and only jointly sufficient to produce a failure and show the human contribution is only one of many (30).

The psychophysical state of workers can play a significant role in a developing of occupational accidents. The risk of being involved in an occupational accident was about two fold among heavy sharers and increased by 50% among men suffering from obstructive sleep apnea syndrome. Reduced vigilance and attention due to sleep disordered breathing are the proposed mechanisms behind the results (28). Hearing and visual impairments are risk factors for occupational injuries (29). Workers who reported more anxiety reported more injuries and took fewer safety precautions (13).

CAUSE OF INJURY

A distinction must be made between cause of accident and cause of injury. External cause categories for work related injuries are motor vehicle crashes cuts, falls, electrocutions, machine related incidents, being struck by falling objects, being hit by moving objects, caught in, under or between, contact with temperature extremes, contact with radiation, caustics, toxic and noxious substances (20,31,32).

PREVENTION

Prevention of occupational injuries is an important task of human resource management. Intervention to reduce occupational trauma should be multi-factorial to be successful. Activities on different levels, workplace visits, risk assessment activities, development projects targeting certain risks, print media and electronic media campaigns, attitude surveys among the general public need to be combined in order to influence claims incidence and underlying occupational morbidity. In depth analyses of the specific tasks and risk exposures identified together with a systematic collection of risk scenarios from exposed workers through critical incident and other techniques, should be the next step of intervention. Occupationally and task related appropriate engineering, ergonomics and design solutions should be developed for the different problems highlighted above. The choice of such applied development activities should be made with a priority towards

reducing injury severity. Substantial reductions in non fatal injuries may reflect changes in work organization, increased automation and improved safety standards. Knowledge of predictors of work related injury, comprehensive training for workers may contribute to injury prevention strategies especially among newly employed workers (17). Development of a standardized surveillance occupational injury database across companies with different database configuration is feasible (33). Personal protective equipments dramatically reduced injuries incidence severity and days lost to medical leave (34,35).

REFERENCES

1. Leigh JP, Cone JE, Harrison R. Costs of occupational injuries and illnesses in California. Prev Med 2001; 32(5): 393-406.
2. Keogh JP, Nuwayhid I, Gordon JL, Gucer PW. The impact of occupational injury on injured worker and family: outcomes of upper extremity cumulative trauma disorders in Maryland workers. Am J Ind Med 2000; 38(5): 498-506.
3. Carlesi R, Casini A, Bonalumi F. Post-traumatic aneurysm of the hand: 3 clinical cases. Med Lav 2000; 91(2): 142-147.
4. Foye PM, Stitik TP, Nadler SF, Chen B. A study of post-traumatic shingles as a work related injury. Am J Ind Med 2000; 38(1): 108-111.
5. Russell P. Reducing the incidence of needle stick injuries. Prof-Nurse 1997; 12(4): 275-277.
6. Carstensen O, Rasmussen K, Hansen ON. Post-traumatic stress disorder following an occupational accident. Ugeskr Laeger 1999; 161(9): 1275-1281.
7. Bowen A, Neumann V, Conner M, Tennant A, Chamberlain MA. Mood disorders following traumatic brain injury: identifying the extent of the problem and the people at risk. Brain Inj 1998; 12(3): 177-190.
8. Baker RS, Wilson RM, Flowers CW, Lee DA, Wheeler NC. A population-based survey of hospitalized work-related ocular injury: diagnoses, cause of injury, resource utilization, and hospitalization outcome. Ophthalmic Epidemiol 1999; 6(3): 159-169.
9. Collins JW, Smith GS, Baker SP, Warner M. Injuries related to forklifts and other powered industrial vehicles in automobile manufacturing. Am J Ind Med 1999; 36(5): 513-521.
10. Fine M. The epidemiology of work and work-related disease in Rhode Island, 1876-2001. Med Health RI 2001; 84(6): 189-191.
11. Takala J. Global Estimates of Fatal Occupational Accidents, Epidemiology 1999; 10: 640- 646.
12. Feyer AM, Williamson AM, Stout N, Driscoll T, Usher H, Langley JD. Comparison of work related fatal injuries in the United States, Australia, and New Zealand: method and overall findings. Inj Prev 2001; 7(1): 22-28.
13. Struttmann TW, Scheerer AL. Fatal injuries caused by logs rolling off trucks: Kentucky 1994-1998. Am J Ind Med 2001; 39(2): 203-208.
14. Robinson CF, Petersen M, Sieber WK, Palu S, Halperin WE. Mortality of Carpenters' Union members employed in the U.S. construction or wood products industries, 1987-1990. Am J Ind Med 1996; 30(6): 674-694.
15. Conway GA, Lincoln JM, Husberg BJ, Manwaring JC, Klatt ML, Thomas TK. Alaska's model program for surveillance and prevention of occupational injury deaths. Public Health Rep 1999; 114(6): 550-558.
16. McCurdy SA, Carroll DJ. Agricultural injury. Am J Ind Med 2000; 38(4): 463-480.
17. Barreto SM, Swerdlow AJ, Schoemaker MJ, Smith PG. Predictors of first nonfatal occupational injury following employment in a Brazilian steelworks. Scand J Work Environ Health 2000; 26(6): 523-528.
18. Bull N, Riise T, Moen BE. Compensation for occupational injury and disease in Norway: ranking of job groups. J Occup Environ Med 2000; 42(6): 621-628.
19. Ivens UI, Lassen JH, Kaltoft BS, Skov T. Injuries among domestic waste collectors. Am J Ind Med 1998; 33(2): 182-189.
20. Bull N, Riise T, Moen BE. Occupational injuries to fisheries workers in Norway reported to insurance companies from 1991 to 1996. Occup Med 2001; 51(5): 299-304.
21. Lymer UB, Schutz AA, Isaksson B. A descriptive study of blood exposure incidents among healthcare workers in a university hospital in Sweden. J Hosp Infect 1997; 35(3): 223-235.

22. Bull N, Riise T, Moen BE. Occupational injuries reported to insurance companies in Norway from 1991 to 1996. J Occup Environ Med 1999; 41(9): 788-793.
23. Rubenstein H, Sternbach MR, Pollack SH. Protecting the health and safety of working teenagers. Am Fam Physician 1999; 60(2): 575-580.
24. Dunn KA, Runyan CW, Cohen LR, Schulman MD. Teens at work: a statewide study of jobs, hazards, and injuries. J Adolesc Health 1998; 22(1):26-28.
25. Crandall CS, Fullerton L, Olson L, Sklar DP, Zumwalt R. Farm-related injury mortality in New Mexico, 1980-91. Accid Anal Prev 1997; 29(2): 257-261.
26. Rivara FP, Thompson DC. Systematic reviews of injury-prevention strategies for occupational injuries: an overview. Am J Prev Med 2000; 18(4): 1-3.
27. Simpson CL, Severson RK. Risk of injury in African American hospital workers. J Occup Environ Med 2000; 42(10): 1035-1040.
28. Ulfberg J, Carter N, Edling C. Sleep-disordered breathing and occupational accidents. Scand J Work Environ Health 2000; 26(3): 237-242.
29. Zwerling C, Sprince NL, Davis CS, Whitten PS, Wallace RR, Heeringa SG. Occupational injuries among older workers with disabilities: a prospective cohort study of the Health and Retirement Survey, 1992 to 1994. Am J Public Health 1998; 88(11): 1691-1695.
30. Dekker S. Accidents are Normal and Human Error Does Not Exist: A New Look at the Creation of Occupational safety, Int J Occup Safety and Ergonomics 2003; 9(2): 211- 218.
31. Forst LS, Hryhorczuk D, Jaros M. A state trauma registry as a tool for occupational injury surveillance. J Occup Environ Med 1999; 41(6): 514-520.
32. Ore T, Stout NA. Traumatic occupational fatalities in the U.S. and Australian construction industries. Am J Ind Med 1996; 30(2): 202-206.
33. Yager JW, Kelsh MA, Zhao K, Mrad R. Development of an occupational illness and injury surveillance database for the electric energy sector. Appl Occup Environ Hyg 2001; 16(2): 291-294.
34. Sorock GS, Lombardi DA, Hauser RB, Eisen EA, Herrick RF, Mittleman MA. A case-crossover study of occupational traumatic hand injury: methods and initial findings. Am J Ind Med 2001; 39(2): 171-179.
35. Prezant DJ, Freeman K, Kelly KJ et all. Impact of a design modification in modern firefighting uniforms on burn prevention outcomes in New York City firefighters. J Occup Environ Med 2000; 42(8): 827-834.

MULTIDISCIPLINARNI ASPEKTI NEZGODA I POVREDA NA RADU

Jovica Jovanović, Mirjana Aranđelović, Milan Jovanović

Nezgode na poslu i njima izazvane povrede i smrt imaju mnogobrojne uzroke i prusutne su kod velikog braja radnika različitih zanimanja i profesija. Mnogobrojni faktori i rizici doprinose povredama na radu. Najčešće su to profesionalne štetrnosti, uslovi na radnom mestu, tehnološki proces rada, organizacioni, ekonomski i ostali socijalni faktori. Veliki je broj teorija koje pokušavaju da objasne nastajanje nezgode i povrede na radu, ali još uvek ne postoji jedinstveno tumačenje koje može da objasni nastajanje svake povrede i nezgode. Različite su mere prevencije i one zavise pre svega od radnog mesta. One podrazumevaju kontrolu radnih mesta od strane inženjera zaštite na radu, preventivne mere, tehnološka rešenja i ulaganja u menađžment, sigurnost, kontrolu rizika, edukaciju i trening. Istraživanja u ovoj oblasti i primena rezultata ovih istraživanja u praksi zahtevaju multidisciplinarni pristup.

Ključne reči: *Nezgode na poslu, povreda na radu, profesionalne štetnosti, radnici, industrija.*