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Injury-Specific Novel Safety Training Helps to Reduce Injuries in the Renewable Energy Generation Sector

Madiha Ahmed and Naira Campbell-Kyureghyan

CARGI, University of Wisconsin-Milwaukee

Corresponding author's Email: campbeln@uwm.edu

Author Note: Madiha Ahmed is a currently a PhD student in Industrial and Manufacturing Engineering specializing with a focus in Ergonomics and Occupational Safety. Dr. Campbell-Kyureghyan is a Professor and Chair in the Department of Industrial Engineering and Director of the Consortium for Advanced Research in Gas Industries (CARGI) at UWM.

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Abstract: Due to the unpredictable industry work nature, safety training programs are implemented within utility companies as an injury prevention countermeasure. These programs are designed to help employees identify and mitigate risk hazards encountered while on the job in efforts to provide a safe workplace. Such training programs are lacking in the renewable energy generation sectors. This study assesses the effectiveness of injury-specific novel safety training programs that were developed for the wind and solar energy generation sectors. Emphasis was placed on example injuries and fatalities due to being struck by or caught between objects during the construction phase of wind and solar farms.

Training programs were designed and delivered to employees within renewable energy generation. Program materials were based on onsite observations, interviews with industry personnel, ergonomic principles, and review of injury records, with particular emphasis on struck by or caught between injuries for this paper. Learning assessments were administered immediately before and after each training session to determine the baseline knowledge and knowledge gained from the training, respectively. Post-training injury assessments were used to determine the training effectiveness at injury reduction.

Results indicate that the knowledge that trainees gain can be directly related to behavioral changes and injury rate reduction attributed to struck by or caught between objects. This presentation discusses the transitioning of such knowledge to the workplace through root cause analysis of injury and fatality records. This study also highlights the benefits of the training program as well as the need for evaluation of training programs to be done on a per topic basis.

Keywords: renewable energy, safety training, training evaluation

1. Introduction

Over 82,000 MW of energy in the United States was generated due to wind capacity by the end of 2016, making it the largest source of renewable energy (“Wind Energy,” 2017). This reliance on wind energy has no chance of slowing down with current predictions indicating that over 20% of the nation’s electricity use will be generated by wind (“Wind Vision Report,” 2015). More wind technicians needed to be hired to meet this growing demand. Over a hundred thousand workers were employed in the US Wind Industry in 2016, a 32% increase in workers in the industry over 2015 (“U.S. Wind Power,” 2017). Even with the need to meet this high demand of energy, the occupational and safety health aspect for wind energy is almost nonexistent.

To date, there exists no OSHA standards specific to the wind industry. Instead, a combination of General Industry and Construction standards are typically used. The underlying assumption is that hazards faced in the wind industry are similar to those in other known workplaces and the standards can therefore be applied to the wind industry. Yet, the dynamic and unpredictable work nature during the construction, installation, and maintenance of wind turbines and the design of the turbine itself present unique challenges and barriers making it difficult to adhere to the OSHA standards and even more difficult to implement controls to increase workplace safety. Thus, training programs are implemented as an injury prevention countermeasure. The goal of such trainings programs is to teach employees how to identify and mitigate the risk factors encountered while at the workplace.

The desired outcomes of these training programs might be easier to achieve if the training content is applicable or customized to meet the demands of the industry being trained. Injury root cause analysis, injury record review, onsite observations, and interviews with industry personnel will help prioritize and organize the content of the training program for better results. These specific training programs are lacking for the renewable energy sector. Instead companies implement generic safety programs. The hazards discussed are common to other workplaces, but the unique challenges brought by the turbine design are not covered making achieving the desired results less likely. Thus, the goal of this study was to assess the effectiveness of an injury-specific training program developed for the wind energy sector with special emphasis on injuries due to being struck by/caught between.

2. Methods

Training programs specifically targeting risk factors in the wind industry were designed based on onsite observations, interviews with industry personnel, ergonomic principles, and review of injury records. Materials include activities involving both industrial and residential sizes of wind turbines during all phases of construction, installation, and maintenance of a wind farm. Field task crew observations were videotaped and incorporated into training materials. Interviews and observations revealed that wind turbine designs vary vastly between manufacturer and even between models of the same manufacturer. This discovery translated to the same tasks being performed differently based on the turbine. Hence, training materials incorporated observations from multiple wind turbines manufacturers and models.

2.1 Material Specific to Struck by/Caught between

The training material was organized by hazards observed in the field as well as injury records. Being struck by/caught between is consistently cited as one of the top three sources of non-fatal injuries requiring days away from work in the utility industry (BLS, 2012) and one of the leading causes of fatalities during construction activities (Hinze et. al, 2005). OSHA identifies struck by and caught between as two of the top four focus hazards contributing to fatalities during construction. The material related to being struck by/caught between begins with workers identifying different ways of being injured. Mixed throughout the material are interactive exercises where trainees recognize the hazards observed while working in the field using videos taken by the research team and suggest solutions. Better practices are also presented to the trainees.

2.1.1 Injuries and Near Misses Specific to Struck by/Caught between

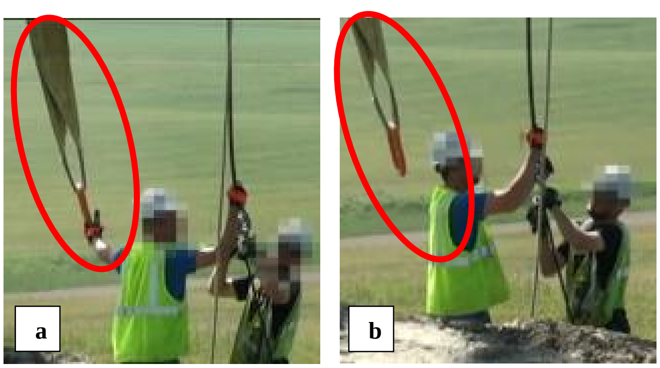

Figure 1 (a and b): Example of near miss struck by injury incorporated into training material.

Injuries were tracked using incidents reported to OSHA, interviews with managers and industry personnel, research and reports, and overseas databases such as the Caithness Windfarm Information Forum (CWIF). Key words to identify noted within injury records included contusion, struck by, caught between, cut, laceration, puncture, crushed, and more. While in the field, near misses involving where workers were almost injured by being struck by/caught between objects were videotaped and incorporated into the training material. Other injuries reviewed either from

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interviews or injury records were illustrated and used to demonstrate the perils of injuries related to being struck by/caught between. Examples of some injuries and near misses are highlighted in Figures 1 and 2. Figure 1 (a and b) depicts a near miss struck by injury. The worker releases the shackle to detach the crane sling (Figure 1a). The shackle freely swings around almost hitting the worker's head multiple times (Figure 1b). Figure 2 illustrates a crushing fatality that occurred during the maintenance phase of a wind turbine. The employee was working in a confined space to perform rotor maintenance. Another employee was handing a wrench to the employee and accidentally pushed the stop button, starting the rotors and thereby crushing the employee. More examples of injuries, near misses, and potential fatalities are depicted within the training. Trainees are prompted to identify the hazards involved in each task. Potential injury prevention countermeasures are then presented and discussed along with other better practices to reduce struck by/caught between hazards observed in the field.

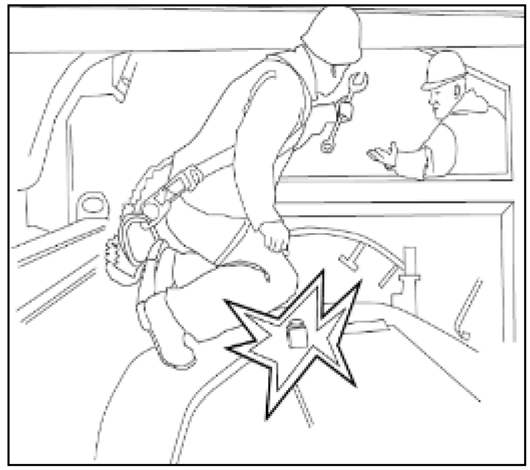

Figure 2: Example of crushing fatality

2.2 Training Program Evaluation

A training workshop was conducted onsite at a utility company servicing the wind energy sector. Several forms of training evaluation were performed based on Kirkpatrick's training evaluation model (Kirkpatrick et. Al, 1979, 2009). Trainees were provided a feedback questionnaire following the program to assess the reaction to training. This feedback questionnaire consisted of seven question related to the trainer and training effectiveness, eight questions were related to demographics, and an open response question for suggestions. Learning assessments identical in content and format were administered immediately before (pre-tests) and after (post-tests) the training session. Pre-tests determine the baseline ergonomic knowledge while the latter test was used to note any change in knowledge because of training. Of the 15 questions, one question was specifically written to test the worker's knowledge of injury prevention related to struck by/caught between injuries (Table 1). One year after training, follow-up was conducted with the training facility to assess the effects of the training and discuss issues observed in the field. Employees were administered identical learning assessment at this time to measure the ergnomic and safety knowledge retained.

Table 1. Question highlighting hazard prevention of injuries related to being struck by/caught between

Question: Recommendations to prevent struck by/caught between injuries include:	
A.	Wearing the correct PPE
B.	Maintaining clearance between you and any fixed or moving objects/equipment
C.	Walking under suspended loads
D.	Communicating with team members
E.	A, B, & D
F.	I don't know

2.2.1. Demographic information

Twelve employees and four managers attended this training session. All trainees were male. The average age of these sixteen trainees was 35.1 years (± 8.9 years) with an age range of 23 – 55 years old. All but one trainee identified themselves as being White, Non-Hispanic. Every trainee had obtained at least a high school diploma/GED. Eighty-eight percent of the trainees indicated having received ergonomic training prior to this specific training program. Amongst this group of trainees, industry experience ranged between 1 and30 years, with the median year of experience of being 7.3. All trainees indicating working either 10 years or less with this utility company at the time of training.

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3. Results

Trainees could rank the overall quality of the training, interaction level, trainer's attitude, trainer's knowledge of topics and the handouts on a 5-point scale of excellent to poor. Results from all sixteen trainees are displayed in Figure 3. Overall, the training was positively received. No trainee ranked any aspect of the training less than satisfactory. All trainees rated the trainer's knowledge of topics and attitude of the training as either excellent or good. Even though there were no ratings less than satisfactory given, the lowest ratings of excellent and good were given for interaction level (69% of the trainees) and handouts and training aids (88%) respectively. Suggestions for improvements by the trainees included using turbine designs specifically used by the company or to issues related to the training room which was provided by the company. Nevertheless, every trainee indicated trying to apply the knowledge learned to their job.

For each test, passing was considered if 70% of the questions were answered correctly. Overall test scores revealed a gain in ergonomic and safety knowledge following the training (Figure 4). Prior to training, the average pre-test score was 70% (± 13%). Following training, this score increased on average by 22% to 92% (± 8%). All trainees had received a passing score after training (i.e. a score higher than 70%).

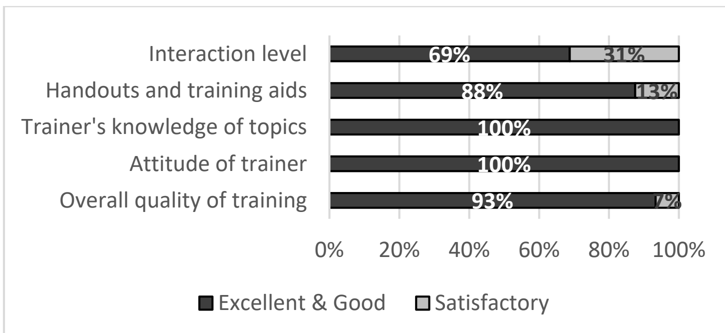

Figure 3: Results of feedback questionnaire

Knowledge gain was observed for the question specifically highlighting recommendations to prevent struck by/caught between injuries (Table 1). Fifty-six percent of the trainees answered that question correctly before training, but after training that proportion increased to 75% of the trainees. All trainees had either answered correctly on the post-test, but not on the pre-test, answered correctly on pre-test and post-test, or answered incorrectly on the pre- and post-tests. The four trainees who did not answer correctly on the post-test had less than 5 years of experience with the company. One of these trainees had over 30 years of experience in the industry while the other three had between 5 and 7 years of industry experience.

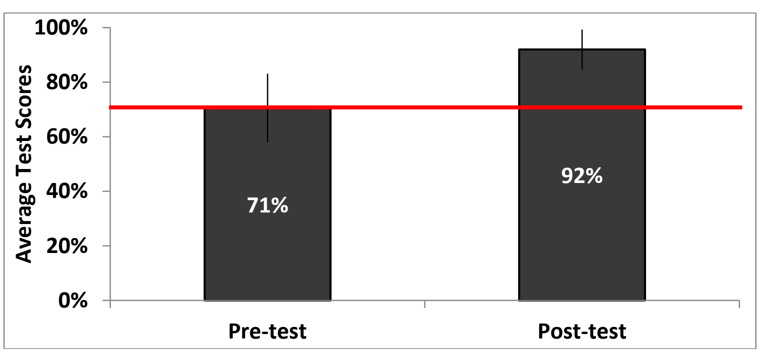

Figure 4: Average Score of Pre-Test and Post-Test

Follow-up via phone was conducted with the company 18 months after the training. Conversations with onsite safety personnel revealed no major injuries attributed to worker(s) being struck by/caught between during this time, but some potential near misses. The primary issue for this company was dropped tools that could either lead to injuries or damage to the equipment. Further probing revealed that the particular wind turbine models at this company required the use of internal hoists to transplant tools to the nacelle. However the bags used to transport those tools did not close properly; thus increasing the likelihood of struck by injuries to workers or damage to equipment.

4. Discussion and Conclusion

This paper investigates the effectiveness of a novel training program that is specific to injuries encountered in the wind industry, and r evaluates the effectiveness of this program towards injuries attributed to being struck by/caught between. A review of injuries and fatalities attributed to being struck by/caught between revealed the predominant reason for injuries are related to human behavior/lack of awareness.

This study found that trainees do in fact gain knowledge on mitigating this hazard while in the field following training which can relate to behavioral changes while on the job and specifically to injuries related to being struck by/caught betweenEven though training was generally positively received (no ratings given below satisfactory), there were still suggestions for improvements to the training revolving around including the specific turbines used at the company.

Surprisingly, the development and delivery of this training program also revealed that injuries and fatalities can also be prevented by incorporating changes that go beyond the employees and management of wind turbine energy providers or construction firms. For example, the fatality described in Figure 2 could possibly be prevented if that emergency stop button was moved from a spot which is likely to be pushed from within the turbine. Other preventable measures include the weight of materials being packed to be considered before being shipped to prevent unnecessary swinging of items or potential overload when heavy items are being lifted using automated methods. These examples provide insight into how training alone will not automatically translate to injury reduction. Employees and managers can take all the necessary precautions, but if there are design flaws that are out of their control, then injuries or fatalities are hard to prevent.

Engineering controls are difficult to implement to reduce the hazards of this injury type, especially in such a dynamic work environment faced by workers in the wind energy. This fact was further confirmed with interviews conducted with industry personnel and training feedback. The resulting underlying theme highlights the lack of standardization among different wind turbine designs and poor designs used within the industry to accomplish necessary tasks. Training employees to identify and reduce hazards in the field based on root cause analysis of injuries can potentially help reduce injuries, but more efforts need to happen in parallel to truly provide a safer workplace for wind technicians. Wind turbine manufacturers and manufacturer of tools with a special emphasis for the wind industry need to be consulted as well to increase the safety of wind technicians when in the field.

Creating this injury-specific training program for the wind industry highlighted areas of improvement for future injury prevention efforts in the wind industry. First, training can help workers identify and mitigate factors in the field, but is more likely to be successful when the content is specific to the wind industry rather than using generic training programs that current wind energy providers distribute to their workers. Secondly, this specific training program highlighted other prevention efforts that can be addressed that go beyond the company and include manufacturers of wind turbines and tool manufacturers. Given the rapid increase in the workforce for the wind industry and the increasing demand of wind generation, the need for a comprehensive training program that is specific to the wind sector is more imminent than ever.

5. References

Bureau of Labor Statistics. (2012). Retrieved from https://www.bls.gov/iif/oshwc/osh/case/ostb3206.pdf

Hinze, J., Huang, X., & Terry, L. (2005). The nature of struck-by accidents. *Journal of Construction Engineering and Management*, *131*(2), 262-268.

Kirkpatrick, D.L (1970). Evaluation of Training. In P. Browning, *Evaluation of Short-Term Training in Rehabilitation,* (pp 35-57).

Kirkpatrick, D. L. (2009). *Evaluating Training Programs: The Four Levels* . (pp 21-27). Tata McGraw-Hill Education

United States Department of Energy. (2015). Wind Vision : A New Era for Wind Power in the United States. Retrieved from https://www.energy.gov/sites/prod/files/WindVision_Report_final.pdf.

U.S. Wind Power Achieves Landmark Installed Capacity of 82,000 Megawatts. (2017, February). Retrieved from https://energy.gov/eere/wind/articles/us-wind-power-achieves-landmark-installed-capacity-82000-megawatts

Wind Energy Facts at a Glance. (2017, February). Retrieved from http://www.awea.org/Resources/Content.aspx?ItemNumber=5059&navItemNumber=742

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