# Occupational Risks Associated with Solar Installations: A Review

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**Abstract**

It is crucial to continuously review and assess the occupational risks associated with rooftop and ground-mount photovoltaic (PV) installations in the United States (U.S.) Solar industry. The Engineering, Procurement, and Construction sector of the U.S. Solar industry is growing rapidly and the current literature that investigates the occupational risks PV installers are exposed to is limited. This paper explores the musculoskeletal disorder (MSD), falls from elevated working surfaces, electrical, and heat stress risks installers face during PV installations. The environmental factors and working conditions that increase the severity of these risks are identified. Practical solutions are then presented regarding the engineering, administrative controls, and Personal Protective Equipment (PPE) required to mitigate these risks. Where published literature is lacking, the effects of these risks in comparable occupations with similar tasks to PV installers is explored in order to propose solutions. This research can aid occupational safety and health professionals to develop safety protocols that can reduce occupational hazards and ensure worker safety during PV installations.

*Keywords: occupational risks, photovoltaic, installations, safety, ergonomics*

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## 1. Introduction

There is a core need to review and assess the occupational risks associated with rooftop and ground-mount photovoltaic (PV) installations within the Engineering, Procurement, and Construction (EPC) sector of the United States (U.S.) Solar industry. PV installers are exposed to (i) musculoskeletal disorder (MSD) risks from repetitive work at awkward postures (Hanson & Thatcher, 2020), (ii) falls from elevated working surfaces, (iii) electrical risks and hazards (e.g., electric shock, burns, electrocution and arc flash hazards), and (iv) heat stress from working for prolonged periods in hot temperatures (Hanson & Thatcher, 2020; Solar Energy Industries Association [SEIA], 2006). Injuries resulting from these risks can lead to a loss of income, a decrease in productivity, an increase in workers' compensation premiums for employers, discomfort, pain, and death (Fatality Assessment and Control Evaluation Program [FACE], 2020; National Institute for Occupational Safety and Health [NIOSH], 2013; SEIA, 2006).

The EPC sector of the U.S. solar supply chain is growing rapidly. In the past decade, the volume of PVs installed has grown at an average rate of 48% annually (SEIA, 2020) and the installation workforce has increased by 269% (The Solar Foundation, 2020, p. 23). A key component in sustaining the growth and continuous improvement of the solar EPC sector is understanding and mitigating occupational injuries. However, there is a lack of literature that addresses the effects of occupational risks and injuries directly on PV installers. Solar safety manuals and investigations tend to focus on falls from elevated working surfaces and electrical risks but do not extensively address musculoskeletal disorders (MSD) or the heat stress risks installers face (FACE, 2020; SEIA, 2006). Moreover, available solar worker accident reports indicate that insufficient Personal Protective Equipment (PPE), administrative and engineering controls are significant causes of PV related occupational injuries and fatalities (FACE, 2020). Consequently, this paper aims to review the occupational risks associated with rooftop and ground-mount PV installations and provide practical solutions (i.e., safety engineering, administrative controls, and PPE) to mitigate them. Where published literature lacks research


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directly related to PV installation, practical solutions are proposed based on similar occupations with comparable tasks. This research can serve as a foundation to guide future investigations into the occupational injuries associated with PV installations. Furthermore, it can help occupational safety and health professionals develop safety protocols that reduce occupational hazards and increase productivity on-site while also providing an overall safe environment for PV installers.

## 2. Musculoskeletal Disorder (MSD) Risks

Musculoskeletal disorders (MSDs) are injuries that damage the musculoskeletal system (i.e., muscles, nerves, tendons, joints, ligaments). They are caused by performing tasks that involve repetitive motion, force, vibration, and awkward postures (Albers & Estill, 2007). The 2018 survey of occupational injuries and illnesses reported that work-related musculoskeletal injuries account for 30.3% of days-away-from-work cases in the U.S. private industry (U.S. Bureau of Labor Statistics, 2019, p. 20). During both rooftop and ground-mount PV installations, installers are exposed to MSD risks associated with performing repetitive manual handling tasks and the frequent use of vibrating hand and power tools. Hanson and Thatcher (2020) point out that solar panels can be challenging to handle due to their size and weight. Manual handling tasks that are typically involved in PV installations include, but are not limited to, lifting, lowering, pushing, pulling, and carrying panels and their constituent parts from one location to another within the installation area (Solar Energy Solutions Group, 2008). These tasks can increase the risk of sprains, strains, and soft tissue injuries (NIOSH, 2013). These injuries are normally involved with manual handling tasks in the residential construction domain, whose manual handling tasks are similar to solar installers. Thus, common soft tissue injuries that are likely associated with these types of manual handling tasks for solar installation work include, but are not limited to, shoulder injuries (e.g., rotator cuff bursitis, tendinitis, and tears), and back injuries (e.g., hip-low back strain, bulging or herniated discs, pinched nerves, L5-S1 damage) (NIOSH, 2013). Moreover, PV installers are also exposed to the risk of contracting Hand-Arm Vibration syndrome (HAVS) (Vergara et al., 2008; Weir & Lander, 2005) from the frequent use of vibrating hand and power tools such as drills and saws (U.S Bureau of Labor Statistics, 2020). These MSD risks can be exacerbated by working in extreme weather conditions (e.g., heat, wind, rain) or on various angled working surfaces (i.e., flat, sloped, or elevated) (Hanson & Thatcher, 2020, p. 180).

The MSD risks associated with PV installations can be mitigated by conducting site-specific ergonomics programs and utilizing lifting tools and equipment to eliminate unnecessary lifting. Choi (2008), conducted a study to identify the work-related MSD and effective safety practices for construction workers. They emphasize the importance of employers creating and implementing a site-specific ergonomics program that identifies and educates workers about the lifting and manual handling hazards present in unique sites. Another strategy for reducing ergonomic stress during lifting is to store materials on the work-site strategically. Ergonomics manuals typically recommend storing materials close to their use location, between knee and chest height, for ease of lifting (NIOSH, 2013). Employers can also place restrictions on the maximum load an individual can handle based on various ergonomic safety factors. These factors include the workers' strength, fitness, medical health, lift duration, postures assumed during the lift, and the availability of lifting equipment (Choi et al., 2016; Health and Safety Executive, 2016). Workers should also be encouraged to take short breaks as needed during manual handling to rest their muscles and joints (NIOSH 2013) and regularly stretch and exercise (Ludewig and Borstad, 2003). Simple tools and equipment, such as dollies and carts, can be used to safely transport materials short distances (NIOSH 2013; Solar Energy Industries Association, 2006). Reduced vibration tools and anti-vibration gloves can be used to mitigate the risk of contracting HAVS (Albers & Estill, 2007). Powered and mechanical lifting equipment such as cranes, and fork trucks can be used to transport heavy materials for longer distances (NIOSH 2013). Hoists can be used to lift solar panels up to elevated working surfaces, manually lifting panels up to these surfaces can increase the risk of MSDs and also result in increased risks of workers falling from elevated working surfaces (SEIA, 2006).

## 3. Falls from Elevations

Falls from elevated surfaces are the most significant contributing occupational hazard to fatalities in the construction industry (Dong et al., 2019; U.S. Department of Labor, 1990). In 2018, 33.5% of occupational fatalities in the construction industry involved fall related accidents (Occupational Safety and Health Administration, 2018). PV installations performed on elevated working surfaces expose installers to the risk of falling from dangerous heights. Based on the most frequent fall accident locations and occurrences in the construction industry over time, falls from elevations are likely more prevalent among rooftop PV installers with the majority of falls occurring at elevations of 30 ft or less; from ladders, roofs, scaffolds, and floors with openings (Dong et al., 2019; Huang & Hinze 2003). Roofers, in particular, have the highest rates of fatal fall occurrences in the construction industry (Dong et al., 2019; Huang & Hinze 2003). Fall risks increase in extreme weather conditions (e.g., heat, wind, rain). In addition, working with electrical components can cause electrical shocks or trip hazards, which can increase fall risks (Romich & McGuire, 2015; Solar Energy Industries Association, 2006). Rooftop PV installations, in particular, have increased fall risks due to limited walking space, which can cause workers to walk closer to the edge of rooftop hatches and skylights (U.S. Department of Labor, n.d).

Fall occurrences can be reduced by training workers to recognize and safely respond to fall hazards. It is also crucial to provide workers with adequate fall safety devices to protect them during fall incidents. Huang and Hinze (2003) hypothesize that falls are more frequent from elevations of 30 ft or less because workers tend to “misjudge hazardous situations" and “lack or wear insufficient protective work clothing and equipment” at these elevations (p. 268). The Occupational Safety and Health Administration (OSHA) mandates that workers exposed to fall hazards at elevations of 6ft or more must be protected by either a guardrail system, safety nets, or personal fall arrest systems (U.S. Department of Labor, n.d). Workers should, additionally, be trained on how to adequately secure and use ladders as well as keeping the work site free from obstacles that may cause trip hazards (Solar Energy Industries Association, 2006). Although construction workers receive this training, 75% of fatal falls occur from roofs, ladders and scaffolding (Dong et al., 2019), more investigations are required to find the root cause of this phenomena. Regular safety inspections and audits should be performed by management personnel to ensure that the proper fall protection systems and practices are being utilized on-site (FACE, 2011). Prevention through design techniques can also be employed in building designs to prevent fall risks during future PV installations. Prevention through design is a technique whereby potential hazards are identified and mitigated in the design phase of a construction project (Dewlaney & Hallowell, 2012; Dong et al., 2019; Rajendran & Gambatese, 2013). For instance, installing parapets on roofs that comply with OSHA height requirements (Dewlaney & Hallowell, 2012; Rajendran & Gambatese, 2013) can serve as guardrails and reduce fall risks during PV installations. Even with all these protocols in place, there is a relationship between electrical components that can cause electrical shocks or trip hazards and falls.

## 4. Electrical risks and hazards

Tasks performed near electrical components and wiring expose workers to electrical risks and hazards, such as shock and electrocution. Electrocution is the third leading cause of fatalities in the U.S. construction industry accounting for 8.5% of construction fatalities in 2018 (Occupational Safety and Health Administration, 2018). Multitudes of electrical components are involved in installing PV systems, including but not limited to, combiners, inverters, transformers, and the PV modules themselves (SEIA, 2006; White & Doherty, 2017). Moreover, the PV modules themselves are always considered “live” due to their ability to create electricity when activated by sunlight, thus creating an environment where traditional regulations, such as Lockout/Tagout (LOTO), are no longer the primary safety solution. These modules and system components can expose installers to electrical shocks, burns, electrocution, and arc flash, especially when handled poorly insulated tools, and equipment (FACE, 2009; SEIA, 2006). Additionally, extreme weather conditions can exacerbate shock and burn risks. For instance, when manually handling PV modules, rainy conditions can increase shock risks (Romich & McGuire, 2015), while hot and windy conditions can increase the risk of burns (White & Doherty, 2017).

Safety measures to mitigate electrical risks and hazards include worker training and the implementation of good LOTO practices (United States Department of Labor, n.d.). Installers should be trained in identifying shock hazards and should use equipment and tools with proper insulation (SEIA, 2006). Site-specific emergency response plans should also be developed and communicated with local fire and rescue responders to aid preparations in case of emergencies. However, with constant PV activation in sunlight, other procedures for modules in combination with LOTO have been observed differently throughout time. Initially, other procedures considered covering the panels during installation (creating complexity and another element of which to be vigilant), or installing PVs during cloudy conditions (where diffuse light still activates the electricity generation process rendering the point mute) or even installing the systems at night (creating another set of safety issues entirely). These practices no longer occur because more modern installations and modules attempt to mitigate these risks by designing easy, quick-connect wire connections for safety and speed. Ultimately, when unsure about the “live” state of PV components and wiring, installers should assume they are electrically energized and proceed with caution (Romich & McGuire, 2015). When working with electrical components, the proper protective clothing includes rubber insulated gloves and leather protectors (White & Doherty, 2017), fire-rated clothing, arc flash protection, protective eyewear, and safety footwear (Romich & McGuire, 2015). Although these PPEs will mitigate installer risks with respect to electrical hazards, they can cause significant heat stress.

## 5. Heat Stress

Heat stress is caused by working in extreme heat conditions and can result in heat related illnesses such as heat cramps, exhaustion, and strokes (Acharya et al., 2018; Bonauto et al., 2007). In the U.S. over 600 people are killed from extreme heat annually (Center for Disease Control and Prevention, 2019), with workers in the construction industry historically being 13 times more likely to die from heat related illnesses (HRIs) than other industries (Gubernot et al., 2015). PV installers are exposed to HRIs from working in hot temperatures for prolonged periods. Solar panels are typically installed in geographic locations that have a high sun and heat exposure (Hanson & Thatcher, 2020), due to energy density and higher financial rates of return on investment, thus increasing the risk of HRIs. Further, the strenuous activities and PPE (e.g., safety helmets, reflective vests, and safety boots) involved in PV installations can make working in hot temperatures mentally and physically challenging (Acharya et al., 2018; Rowlinson et al., 2014; SEIA, 2006). Signs of HRI’s include, but are not limited to, high body temperature, profuse sweating, confusion, slurred speech, and dizziness (Center for Disease Control and Prevention, 2018).

In order to reduce the risk of HRI’s, installers need fluids and frequent rest in a shaded and cool area (California Department of Industrial Relations, 2015; Hanson & Thatcher, 2020). Work-rest cycles are essential to reducing the effects of heat stress on workers. Work rest schedules can be created for PV installation work using a heat stress index to measure heat effects. The most commonly used heat stress index is the Wet Bulb Globe Temperature (WBGT), which incorporates the air temperature, humidity, radiant heat, and wind speed to quantify heat stress levels (Acharya et al., 2018; Rowlinson and Jia, 2014; Rowlinson et al., 2014). To reduce the effects of heat stress, the workload on-site can start small and gradually increase to allow installers to acclimatize to their environment (Occupational Safety and Health Administration [OSHA], n.d.). It is also vital for employers to continuously monitor workers for signs of HRIs as they work in hot temperature conditions (Hanson & Thatcher, 2020; California Department of Industrial Relations, 2015; OSHA, n.d). Workers can be monitored using physiological signs such as pulse rate, temperature, body weight, blood pressure, respiratory rate, and alertness; their workload adjusted based on these factors (OSHA, n.d).

## 6. Conclusion

This paper explores the occupational risks associated with rooftop and ground-mount PV installations. By assessing these occupational risks, this paper aims to contribute to the continuous improvement of worker health and safety in the solar industry. These occupational risks can be mitigated significantly by solar EPC companies through continuously training installers to identify hazardous situations, developing and promulgating safety protocols that are easily accessible, and providing appropriate PPE to PV installers. When developing safety protocols, it is important to consider how specific occupational risks can exacerbate others. Safety protocols need to be comprehensive and account for the relationship between specific risks. For instance, strenuous lifting in hot conditions while wearing protective clothing can increase the risk of heat stress and, therefore, work-rest schedules should be augmented to address these conditions. Electrical shocks and burns on elevated surfaces can lead to falls from elevations and installers should, therefore, use both fall protection and the necessary electrical protective clothing in these situations. There is a lack of available investigation reports quantifying the rates at which these risks directly affect PV installers. Future work includes conducting questionnaires and worker interviews to assess the risks seen within the community in total, rates of occurrence of each of these risks amongst PV installers, and to understand from the installers perspective the factors that increase the severity and likelihood of these risks.

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