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Original Paper

Crush Injury Risk Awareness, Prevention and Minimisation in Load Shifting Operations

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Abstract

This article considers injuries related to crushing and methods of prevention and minimisation of such injuries, particularly from the perspective of plant operations, where a crush injury occurs when the body or a body part is trapped, pinched or jammed under or between objects (Victoria State Government., 2020). A safe system of work, underpinned by worker awareness, should be implemented and maintained in all load shifting operations in order to minimise or prevent crush injury risks. Employers and workers should participate in inductions, safety meetings and consultation activities to ensure that they are aware of best practices to control crush hazards.

Keywords

Health and safety, crushing hazards, crushing injuries, compartment syndrome, crush injury syndrome, workplace safety

1. Introduction

The Australian Institute of Health and Welfare (2020), referring to the World Health Organisation (2014), state that most injuries, whether unintentional or intentional, are preventable. For a perspective of the prevalence of crush injuries, in 2017-18, over 532,500 cases of injury resulted in admission to hospital in Australia with the main causes of hospitalised injury being falls (42%), followed by injury due to inanimate mechanical forces (14%) and transport crashes (12%), many involving crush injuries (Australian Institute of Health and Welfare, 2020).

A crush injury can result from a number of different types of accidents in the workplace. Workers can be struck by a heavy falling object or crushed between two objects, such as vehicles or a wall and a heavy box, which traps them to the ground. Machinery, either by getting a limb trapped inside or by falling over on a worker or pedestrian, may also cause a crush injury.

If a person is unable to be freed in time, the extremity may need to be amputated. Severe injury may damage the heart and lungs, or even cause death, if the object crushes the chest. The cells within the muscles begin to die the second that blood flow ceases to a region of the body.

2. Discussion

2.1 Crush Injuries Defined

Strauss (2016) outlines that a crush injury occurs when the body or a body part is trapped, pinched or jammed under or between objects. Depending on the degree of force, the pressure may damage the skin, muscles, nerves or bone. If enough force is applied, traumatic amputation occurs. Crush injuries can also cause compartment syndrome or crush injury syndrome, both of which potentially have serious consequences.

When muscles within a “compartment” of a limb swell so much that blood flow is blocked, compartment syndrome may occur. The muscle-covering fascia is not very elastic and does not extend, forcing pressure from the internal swelling, compressing nerves and vessels of the blood. Many situations, like being crushed under a heavy object, may cause it.

Crush injury syndrome occurs when, for many hours, a wide area of tissue is squeezed and deprived of blood flow. This triggers the breakdown of muscle cells, releasing acids and other chemicals. These chemicals are released when the strain is removed and can cause significant harm when they migrate to the heart and kidneys.

Generally, crush injuries occur in one of three scenarios, namely, contact with a machine with moving parts, fall or collapse of construction materials, and contact with mobile equipment (Laffey, Bucci, & Kent., 2020). For workers who come into contact with machinery that allows the body part of a worker to come into contact with a moving part, crush and amputation risks are high. This hazard is commonly seen in punch presses, brake presses or power shear equipment, and is especially common in manufacturing industries. In construction and mining sectors, this can include mobile plant.

Construction collapse accidents or accidents where construction materials fall or otherwise collapse often result in crush injuries and related fatalities. As an example, a collapse of a scaffold can cause the scaffold materials, braces, or other materials to crush a worker below. Further, trench work or excavation work often creates a significant crush danger for workers and others. Finally, crush injuries also happen when another object hits a worker, or a worker may get pinned between two objects. For example, during roll-on-roll-off operations, a dock worker may be pinned or struck by power-driven vehicles when materials are loaded on/off from shipping vessels.

Tragically, crush accidents are fatal at times, however workers are frequently left with debilitating complications should they survive. These injuries appear to affect large parts of the body, and because of nerve and organ damage, there are also long-term consequences. This can also result in an inability to return to work, causing employees and their families’ financial distress. Common crush injuries

include spinal damage and paralysis, internal organ damage, amputations, broken and crushed bones, head and brain injuries, muscle and tendon damage and nerve damage.

2.2 Hazards and General Prevention

Managing the health and safety risks involves a four-step risk management process: Identifying hazards; Assessing risks; Controlling risk; and, Reviewing the process. Risk identification includes finding out what could cause harm (Worksafe Queensland, 2020). Risk assessment requires recognising the extent of the damage that could be caused by the hazard, how extreme the harm could be and the probability of it occurring. Controlling risks requires implementing the most effective control measure that is reasonably practicable in the circumstances. Assessing control measures to ensure they are working as planned is the final step. The results of the review process will determine if any adjustments need to be made in the control measures applied.

Specific precautions are required for each kind of crush injury hazard, but some general tips apply. When using machinery, accidents can occur at any time. Crush injury or amputation of the fingers or hands comprise most injuries (Strauss, 2016).

General safety includes:

- Operators reading the relevant operations manual and manufacturer specifications and pay careful attention to the safety directives.
- Employers making sure that all workers on a particular piece of equipment understand how to operate it safely.
- Ensuring that safety features are not removed or modified. A significant element in crush accidents is the absence of safety guards. Fitting protection shields to cover all moving parts, such as belts and pulleys, where practicable, can reduce the likelihood of these injuries.
- Regularly maintaining and checking your machinery. Strauss (2016) notes that accidents, including crush injuries, are more common if the equipment is old.
- Ensure that clothing such as sleeves and pant legs are not loose or flapping and are unlikely to get entangled in a machine's moving parts. Likewise, Hair should also be tied up.
- Fitting safety signs.
- Not taking shortcuts. For example, taking the time to switch off and isolate machinery prior to undertaking any adjustments.
- Avoiding working alone.

Hands are often the part of the body closest to a hazard, and most research advises the selection and use of gloves as the primary risk management for avoiding hand injuries which is however, the least desirable control option (Queensland Government, 2020). While the risk of lacerations, cuts, burns and chemical contamination can be greatly decreased by gloves, the risk of fractures, crush injuries or amputations does not decrease.

2.3 Crush Injury Prevention in Mobile Plant Operations

When a worker places themselves between the moving load/crane jib and another hard surface, swings the jib over the operator's station while operating a Vehicle Loading Crane or stands between a load being positioned and another hard surface such as a tray truck, they effectively create a crush zone (Australian Rail Track Corporation, 2020). A crush zone puts a worker at risk of crushing injuries. Similarly, suspended loads, such as loads on a Gantry, Vehicle Loading Cranes or Mobile Cranes create hazards crush injury risks.

There are number of Australian workplace examples of crush injuries sustained as a result of a load shifting activity. In one case, for example, as reported by SafeWork NSW (2019), to load large concrete blocks from the ground onto a flatbed truck, a worker used an excavator fitted with forklift tines. It moved while moving the load, pinning another worker, who was assisting with the lift, against the truck, resulting in a suspected fractured pelvis. In another case, after being stuck between the arm of a vehicle-loading crane and the truck it was placed on, a 60-year-old man was crushed and died. The incident occurred when the crane lifted equipment onto the back of the truck and the worker could not be released before emergency services arrived, although the emergency stop was activated (SafeWork NSW, 2020).

As further alternative plant examples, when a concrete pump operator's arm was trapped in moving parts inside the receiving hopper of a concrete pump, the operator suffered serious arm injuries (Workplace Health and Safety Queensland, 2020). Hinz (2019) states that Worksafe Victoria highlight that Elevating Work Platform (EWP) operators often experience significant and fatal injuries as a result of crushing themselves or passengers against overhead or adjacent structures while the EWP is in service. This may involve situations where the EWP basket or platform operates in an environment where structures such as roofing, scaffolding, cables or pipework are fixed overhead or adjacent. Other dangerous circumstances can involve the movement of the EWP basket suddenly due to factors such as uneven terrain, control failure or operator unfamiliarity with controls and ground-based obstacles in close proximity to the EWP that can impact or distract the operator from overhead hazards by disrupting their attention.

Australian Rail Track Corporation (2020) note a number of relevant Australian Standards, codes of practice and industry requirements that should be referred to in crane operations. These include: Managing the risk of falls at workplaces code of practice April 2016; Managing the risks of plant in the workplace code of practice July 2014; AS 1418 Set-2011 Cranes, hoists and winches—Design and Construction; AS 2550 Set-2011 Cranes, hoists and winches—Safe use Set; and, All cranes guidance material—Safe Work Australia. These materials provide best practice guidance in crane operations and should be referred to by all operators to control the risks associated with crush injury.

Liebherr (2011) identify a range of hazards that present a risk of crush injury, including:

- Crane carrier is not driven in a safe manner
- Exceeding axle load limit resulting in reduced braking performance

- Crane travelled in area where space is limited/ travelling up or down ramps
- Damage to crane, other plant or personnel whilst turning or being driven in reverse
- Crane positioned on ground with insufficient load bearing capacity
- Crane positioned in close proximity to slopes/excavations
- Insufficient horizontal alignment (crane positioned on incline)
- Instability/lack of load support from sliding beams/outriggers
- Persons standing in crush zone (counterweight land point)
- Incorrect placement sequence of counterweight/ additional counterweights added to plant
- Falling crane sections
- Cable break during installation of hoist cables
- Persons may be injured during initial and ongoing slewing operation
- Incorrect selection of lifting gear for task
- Arms and legs may be crushed or severed between rope pulley and rope or if rope pulley rotates
- Falling objects resulting from defective rope winches (manual)
- Persons in load/placement zone
- Uncontrolled or swaying load
- Exceeding shut off limits function
- Load may exceed the rated load at a specific working radius
- Persons stepping into the path of the moving machine
- Hook block may collide with boom head
- Load/rigging gear falling due to hoist rope failure
- Rope failure due to wear and tear
- Separation of wedge type rope fittings
- Dogman/Rigger unable to be clearly seen by operator during operation/slewing of crane
- Uncontrolled movement of loads
- Overload of crane
- Overload during dual lift by multiple cranes
- Uncontrolled movement of loads due to wind factor
- Uncontrolled movement of boom during erection/dismantling activities
- Machine exceeds working radius
- Unexpected movement (closure) of open cab door whilst door in inclined position
- Unexpected movement of crane parked in stationery position during unscheduled maintenance activities
- Boom/jib section falling during maintenance activities where unsecured or faulty
- Persons operating in an unlit or poorly lit area

Correspondingly, Liebherr (2011) provide a number of risk controls that should be place, including:

- Certified and competent plant operator to travel crane
- Do not exceed specified axle load
- Dogman to act as spotter for operator
- Crane is fitted with acoustic and visual warning devices
- Driver should use all warning devices when in travel mode
- Reversing of vehicles should be minimized
- Where reversing is required, spotter is to remain in visual contact with the operator at all times
- Reversing shall be undertaken at slow driving (manoeuvring speed)
- Support or drive crane only on ground with required load-bearing capacity
- Before commencing work, obtain as much information about the ground conditions at the work site as possible. This may include information from previous work at the site, results of test bores, natural features and surface drainage
- Crane to be positioned in accordance with permissible ground pressures and safety distances
- Crane shall be horizontally aligned before starting crane operation
- Crane must not be adjusted whilst holding any load
- Crane to be supported in accordance with load charts
- Sliding beams and support cylinders must be matched and fully secured by pins prior to crane operating with load
- Persons landing counterweight shall remain clear of drop and placement zone
- Ensure slewing platform does not collide with raised counterweight frames when turned
- Counterweights shall be installed in accordance with the load chart
- Ensure locking pins are secured
- Installation of components (jib) must be completed in accordance with Manufacturers Instruction manual
- All sections must be appropriately pinned and (and unpinned) where appropriate
- Guy rods must be removed or hung as required
- Competent person must ensure that no slack cable forms
- The cable must run on the inside of the frame formed by the guying
- Short warning signal to be provided before starting a slewing movement
- Visual check for people or objects in danger area prior to operation and ensure controlled by means of soft or hard controls (barricades/work instruction)
- Ropes or rope pulleys must not be touched during operation
- Safe distances must be maintained at all times
- Check manual rope winches and rope for external and functional damage
- Ensure at least two cope coils remain on drum
- Personnel and objects must remain free of movement range of components supported by winch

- Operator to visually confirm no persons are in danger zone
- Operator to exercise extreme caution when lifting load
- When auxiliary winch in use, winch not to be used for lifting loads
- All crane movements to be executed slowly and delicately
- Guide ropes to be used to manage load and prevent swaying
- A load meter is installed with an alarm system attached
- Operators must not exceed relative working radius.
- Crane fitted with hoist limit switch
- Function of hoist limit switch to be checked before every crane application.
- Anti 2 block to be fitted
- Rated pull force of hoist gear must not be exceeded
- All ropes to be visually inspected on a daily basis
- Individual cranes shall be loaded in accordance with the permissible load capacities
- Angular pull is prohibited
- Wind Velocity Meter fitted and Wind chart provided
- Stop work when the velocity of the wind exceeds 10m/sec
- Crane shall only be operated in accordance with maximum permissible wind speeds according to wind chart
- Boom to be retracted where weather conditions are unclear
- Erection/dismantling of boom shall not take place where wind speed exceed maximum permissible according to wind chart
- All works to be carried out within the range of the load chart as supplied, regardless of length of boom installed
- Hands to remain clear of crush zone
- Operator to use caution when opening/closing cabin door
- No persons shall stand under boom or jib whilst mechanical repairs are carried out and sections mechanically secure from falling
- Lighting provided on boom, platform and sliding beams (outriggers)

Reliable and effective methods communication are essential where cranes are in operation. Worksafe Queensland (2018) note that in addition to sufficient exclusion zones, a reliable method of signalling between the crane operator and dogger is essential for safe crane operation and unreliable communication methods may lead to unsafe crane operation resulting in dropped loads or collisions. They further note that an effective means of communication is particularly important where the crane operator cannot see the load, the load's landing area, the travel path of the load, crane or part of the crane, or the dogger or other workers in the work area. It is equally important where crane operator is not in a position to make an accurate judgement of distance or where it is possible for the crane to come into contact with overhead powerlines.

Specifically related to EWP crush injury prevention, Hinz (2019) refers to Worksafe Victoria recommendations for boom type EWP risk control measures. These include the use of physical barriers attached to the basket or platform, pressure sensing devices mounted over the control panel that can detect possible crush accidents and avoid more dangerous movement of the machine, and proximity sensing devices that prevent the EWP basket or platform from manoeuvring within crushing proximity of structures. Control measures for Scissor type EWP can involve the application of a “Lower before travel” policy that specifies that the device must be completely lowered before any movement, thereby fully clearing operators and passengers from any overhead structures before travelling, and driving EWP scissor lift units using the external control (where fitted to the unit) while travelling via doorways or through areas with overhead structures.

2.4 Managing Crush Injuries

The treatment of crush syndrome should concentrate on avoiding the syndrome’s systemic complications and Understanding the pathophysiology of the process and treating it accordingly is essential Banerjee (2020). As the time of entrapment of a limb is directly proportional to the development of crush syndrome, extrication should be prompt.

Banerjee (2020) advises that basic life support measures should commence with assessment of airway, breathing and circulation, especially establishment of intravenous access. If possible, fluid resuscitation, especially in limbs trapped for longer than 4 hours, should be initiated prior to extrication. The risk of concomitant injury (fractures, organ damage, spinal injury and apparent haemorrhage) should also be of concern. High-flow oxygen should be initiated and the patient should be moved as soon as possible to a medical facility.

2.5 Crush Injury Awareness

Employers and training providers can increase crush injury awareness by ensuring hazard awareness and control measures are front of mind for workers responsible for load shifting. Ensuring worker safety means creating a safe effective, positive workplace where productivity can be focused on by employees. In order to insure a safe workplace, contact and involvement between the employer and the employee in relation to safety and health concerns in the workplace are central. Communications should include training workers to handle specific situations using the proper procedures and involvement in hazard identification, risk assessment, risk controls and review of the process.

Worker awareness may take place on-site by holding inductions and toolbox discussions, or off-site by submitting on-line information and asking for feedback; or by using telephone hook-ups. Consultation may also take place by employers talking to subcontractors and asking them to share information with the employees of the subcontractor and pass on any suggestions to the employees.

Managers, workers and subcontractors can use toolbox talks or pre-start meetings to provide information and gain input from employees, as well as to help raise awareness of particular risks. It is considered best practise when using toolbox talks to keep a record of the subject discussed, participants and any input obtained and to track the effectiveness of toolbox talks by safety results such as control

measures implemented and near misses noted. This information sharing processes is conducive to the development of safe systems of work.

In order to collect feedback and ensure toolbox participants keep crush injury hazards in mind, a simple feedback “quiz” could be utilised. Two basic toolbox talk quizzes follow as examples.

Crush Injury Awareness Quiz 1

- 1). What can cause crush injuries?
 - (a) contact with a machine with moving parts
 - (b) fall or collapse of construction materials
 - (c) contact with mobile equipment
 - (d) all of the above
- 2). Removal of guards while a machine is in operation is permissible.
 - (a) True
 - (b) False
- 3). EWP risk control measures include:
 - (a) barriers attached to the basket or platform
 - (b) pressure sensing devices mounted under the control panel that can detect possible crush accidents
 - (c) using wheel chocks
 - (d) None of the above
- 4). Crush injuries can cause:
 - (a) fractures
 - (b) organ damage
 - (c) spinal injury
 - (d) All of the above
- 5). Ignoring load charts increases the risk of crush injuries.
 - (a) True
 - (b) False

Answer key: 1 (d), 2 (b), 3 (a), 4 (d), 5 (a)

Crush Injury Awareness Quiz 2

- 1). Exceeding axle load limit on mobile plant results in reduced braking performance.
 - (a) True
 - (b) False
- 2). Excavator booms, buckets, forklift forks, and other elevating equipment should be _____ when not in use.
 - (a) raised
 - (b) stowed mid-point
 - (c) lowered
 - (d) Any of the above

3). EWP risk control measures include:

- (a) standing in the crush zone
- (b) pressure sensing devices mounted over the control panel that can detect possible crush accidents
- (c) using wheel chocks
- (d) All of the above

4). Crush injuries can cause:

- (a) fractures
- (b) spinal injury
- (c) apparent haemorrhage
- (d) All of the above

5). Where mobile plant is being reversed, a spotter should remain in visual contact with the operator at all times.

- (a) True
- (b) False

Answer key: 1 (a), 2 (c), 3 (b), 4 (d), 5 (a)

3. Conclusion

As condoned by Safety Matters Weekly (2020), there are a number of strategies that should be applied for controlling crushing hazards including use of guarding, blocking and securing objects and increasing awareness of pinning hazards. Employers and workers must ensure guards are used to prevent access resulting in injuries, deaths, and amputations. Removal of guards must be prohibited whilst machinery is in use. Guards must also be engineered in such a manner that workers can not become caught between the equipment and the guard. An effective lockout/tagout system helps to ensure that all sources of potentially harmful energy can be detected and efficiently regulated by employees. Raised equipment should be well supported so it cannot fall and equipment should not be parked or stored in a raised position. Employees should make sure excavator booms, buckets, forklift forks, and other elevating equipment are lowered when not in use. Finally, workers must be aware of mobile equipment in their work area, and ensure that they are never between moving equipment, such as forklifts, and immovable structures, other vehicles, or stacked materials. This exclusion can be supported by restricting traffic in the work area so only essential personnel are present and provision of separate pedestrian and vehicle traffic as much as possible. All of these control measures are underpinned by employers ensuring their workers are trained to identify areas where crushing hazards exist and the control measures they can apply.

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