HEIGHT SAFETY

The Complete Harness and Lanyard Height Safety Guide:

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Executive Summary

This white paper has been created to assist employers, HSE staff and end users understand fall arrest equipment including design, fit, maintenance and training requirements. It also seeks to broadly assist in implementing improved height safety on site including fall prevention measures and worker training.

Focusing on harnesses and lanyards, it analyses deaths and injury types and discusses the forces applied to the body during the moment of impact (MOI) and how those forces can change significantly with different harness designs or individual fit.

Australian Standards are outlined along with the dangers posed by many certified harnesses sold in Australia failing to meet those Standards (despite being certified) due to their off-centre frontal attachment point.

Lanyard requirements are also outlined - including stopping forces in kN - as is the difference between average stopping forces used in AS/NZS 1891.1 and maximum stopping forces used in the American Standard. The paper discusses why lanyards designed to the US Standard and sold in Australia present far greater injury dangers than lanyards designed for the Australian market due to their reduced absorption of stopping forces during the moment of impact.

Suspension trauma and orthostatic intolerance is also analysed, along with an explanation of the Safe Work Australia recommended suspension trauma (Standing Step) strap.

Fall arrest equipment maintenance, worker training and general height safety considerations are also discussed.

Falls from Height Statistics

Falls are a common cause of death and serious injury in Australian workplaces, particularly in construction where it is the most common cause of death(1) and accounts for half of the total hospitalisations.[2]

While there has been a decrease in the fatality rate over the past 20 years, it is still a serious issue, with 232 workers dying from a fall from height during the eight-year period of 1 July 2003 to 30 June 2011 – 29 workers each year, and 11% of workers killed during this period.

Approximately 6900 workers were hospitalised following a fall from height during the three years - July 2006 to June 2009 - more than six workers every day, accounting for 9% of all workers who were hospitalised during this period.[2]

And that is just the tip of the iceberg. In 2010–11, there were 7730 claims for serious injury (requiring a week or more off work and 6.2 weeks on average) lodged due to a fall from a height – that's 21 employees every day falling from height and needing time off work.[2]

Males accounted for three-quarters of the falls-related claims and 98% of falls-related fatalities and older workers are much more likely to be killed or injured in a fall from height – although this is partly explained by the change in the worker profile from 20 years ago.

Interestingly, 50% of the deaths between 2003 and 2011 resulted from falls of three metres or less with falls from ladders accounting for the greatest number of deaths, followed by falls from vehicles and falls from roofs.[2]

Moment of Impact (MOI) Injury Explained

The Moment of Impact (MOI) is the point when a falling worker's fall arrest system engages to stop the worker's fall.

Significant forces can be exerted on the body during this time: up to 25g in a non-absorbed fall and 6kN if a shock absorbing lanyard is deployed. If the appropriate fall arrest system or harness has not been used, or even if the appropriate system is used but is not worn or fitted correctly, serious injuries such as broken ribs, punctured lungs or even death can occur.

Furthermore, a poorly designed or poorly fitted harness can lead to serious head injuries. LINQ's research has found that a significant number of fallen workers are rescued unconscious as a result of fall arrest hardware impacting with their head during the moment of impact. See more in Harness Design.

Nature of Injuries

76% of workers who died as a result of a fall from a height of approximately one metre or more in the four years 2008 to 2011 did so as a result of striking something (usually the ground) or falling into the path of another fatal hazard. Head injuries were the most common cause of death.

8% of those who died did so as a direct result of injuries to their chest and torso while three workers died from deep vein thrombosis after falling and bruising an area of the body.[2]

Data on falls requiring hospitalisation show this was most commonly as a result of an injury to the trunk, accounting for 22% of hospitalisations. This increased to 30% when the fall was from roofs and other structures.

Injuries to the knee & lower leg, elbow & forearm and head & neck followed, accounting for 19%, 16% and 16% of hospitalisations respectively.

Falls from ladders most commonly resulted in hospitalisation as a result of elbow & forearm injuries (23%).[2]

Falls in Construction

The Construction industry accounted for 37% of falls-related fatalities between 2008 and 2011, with falls from buildings, ladders and scaffolding the most deadly work-related accident in construction overall, accounting for 25% of all construction fatalities.[2]

FALLS FROM HEIGHTS IN CONSTRUCTION

- Most common cause of death
- 50% of deaths were caused by a fall of three metres or less.
- Account for half of the total hospitalisations in this industry

Given the prevalence of workers falling from height and associated deaths, hospitalisation and workers' compensation claims, ensuring the best possible height safety procedures are followed is critical.

The 2011 Safe Work Australia Code of Practice for Managing The Risk Of Falls At Workplaces states the risk must be eliminated or minimised so far as reasonably practical by implementing control measures in accordance with the hierarchy of control.

A risk assessment must be carried out to identify all locations and tasks that could cause an injury due to a fall and you must consult with workers and other duty-holders.[3]

Key things to look for include:

- Surfaces stability or fragility
- The potential to slip, for example where surfaces are wet, polished or glazed
- The safe movement of workers where surfaces change
- The strength or capability to support loads
- The slope of work surfaces, for example, where they exceed 7 degrees.
- Levels: where levels change and workers may be exposed to a fall from one level to another
- Structures: the stability of temporary or permanent structures
- The ground: the evenness and stability of the ground for safe support of scaffolding or a work platform
- The working area: whether it is crowded or cluttered
- Entry and exit from the working area
- Edges: protection for open edges of floors, working platforms, walkways, walls or roofs
- Holes, openings or excavations which will require guarding
- Hand grip: places where hand grip may be lost.

In some situations specialists may be required to inspect structural integrity or load bearing capabilities.[3]

Fall-Arrest Systems

PPE is the last line of defence in the hierarchy of control and should be used where it is not reasonably practicable to use higher level control measures.

Fall arrest systems include anything from anchor points to lifelines, inertial reels, fall arrest harnesses, shock absorbing lanyards and more.

This LINQ white paper is focused on harness and lanyard analysis but regardless of the fall arrest system or component, correct function requires that workers wear, fit and use it correctly, meaning training is critical.[3]

THE IMPORTANCE OF HARNESS FIT AND TRAINING

For a harness to function correctly and do the job it is designed for, it must be correctly fitted, or it can cause significant injury and potentially lead to death at the Moment of Impact (MOI).

Correctly fitted means both ensuring it is the right size for the individual as well as ensuring it is worn and adjusted correctly.

An incorrectly fitted harness changes the force distribution during the MOI.

Often workers think they are wearing a harness correctly when they are not and workers must understand the importance of fit and be provided with training and use of all fall arrest equipment.

Harness brand selection is also an important variable here. As well as reducing the likelihood of injury in the Moment of Impact (see Harness Design page 10) good harness design will shepherd the worker into correctly fitting their harness, reducing the likelihood of serious injury.

LINQ's fitting guidelines recommend webbing sits snugly under the buttocks and the chest strap sits just below the sternum. If the harness cannot be fitted in this manner, it may be the incorrect size or contain design attributes that fall short of best practice.

THE IMPORTANCE OF TRAINING

Employers must provide information, training and instruction to workers including but not limited to[3]:

- Procedures for emergency and rescue.
- Type of control measures used to prevent falls
- Procedures for reporting fall hazards and incidents
- The correct selection, fitting, use, care, inspection, maintenance and storage of fall-arrest and restraint equipment
- The correct use of tools and equipment used in the work
- Control measures for other potential hazards (eg electrical hazards)

Harness Design

With the forces applied to the worker during the moment of impact having the potential to cause trunk injuries such as broken ribs and internal organ damage, minimising those forces is of the utmost importance.

The Australian Standard (AS/NZS 1891.1) states that surviving a fall with minimal injury "will depend principally on the decelerating forces imposed on the body during fall-arrest and the manner in which those forces are transmitted to the body".[4]

While the lanyard is the principal fall arrest component for reducing those forces - which the Standard states must be no more than 6kN (See Lanyards Page 14)[4] - the harness controls how those forces will be transferred into the body and variances in harness design can mean the difference between walking away unharmed and suffering a serious injury.

Choosing a harness that has certification of compliance to Australian Standards (AS/NZS 1891.1) - rather than 'stated' compliance - should be a minimum requirement however there are major design differences even among certified harnesses, discussed below.

LINQ has found that a concerning number of workers are rescued unconscious after a fall from height due to fall arrest hardware impacting their heads during the moment of impact as a result of poorly designed harnesses.

Certified Product™
Australian Standard
AS/NZS 1891.1:2007
Lic:21481
SAI Global

REAR ATTACHMENT POINT SETUP:

Many Australian certified harnesses have a rear attachment point that is designed with a floating rear dee setup (see figure breakout) that increases the likelihood for serious injury during the moment of impact.

With forces of up to 6gs being exerted on the harness and associated floating rear dee attachment point during the Moment of Impact, it is common that the dee will violently migrate upwards and there is a risk it will completely break through the rear plastic insert / holder, smashing the worker in the back of the head.

The use of a 'closed loop system' as found in LINQ harnesses means that the dee cannot move during the moment of impact, resultantly keeping the karabiner, snap hook or other fall arrest attachment hardware away from the fallen or falling worker's head.

A floating rear dee is identified by the manner in which a dee is held in place, which is often by means of a plastic insert holding the dee through which the harnesses' back straps are threaded.

FRONT ATTACHMENT POINT SETUP:

The Australian Standard (AS/NZS 1891.1) states that a fall arrest harness must have a **central front attachment point**, however many harnesses have an attachment point that is positioned left of centre[4] in contravention of the standard and despite having third party accreditation of compliance.

During the moment of impact an off-centre attachment point will exert significant vectorial (diagonal) forces across the body, increasing the likelihood for chest, torso and trunk injuries, such as broken or cracked ribs or punctured lungs.

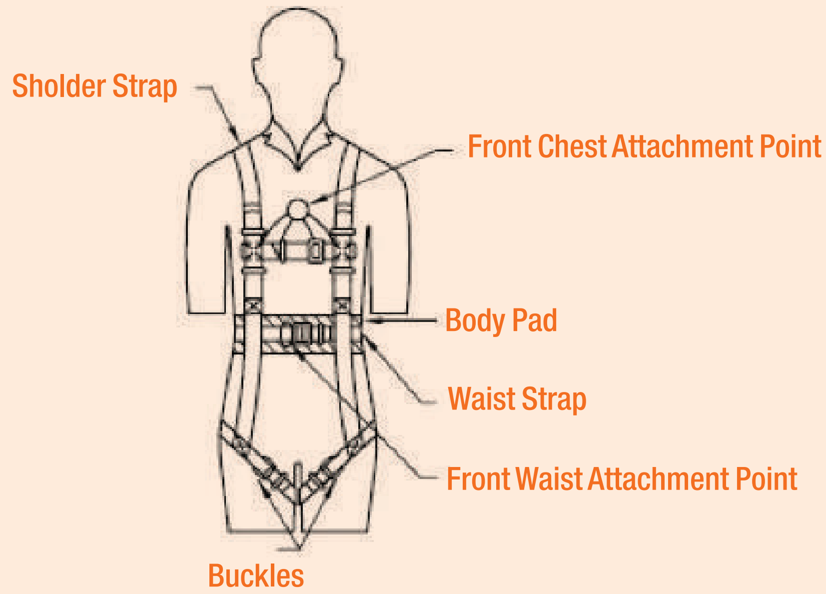
Furthermore, the off-centre frontal attachment point is created with a metal dee for attaching a lanyard that - like the floating rear dee setup - significantly increases the likelihood of head or facial injury at the moment of impact.

Further risk to chest or rib cage injury comes from the torsional force, or twist, applied to the frontal dee at the moment of impact. The dee has a flat end which may violently dig into the chest as it it twisted and wrenched upwards.

The use of a harness such as LINQ with a pair of co-joined belay loops as its central front attachment point will significantly reduce the likelihood of a vectorial force and subsequent trunk injuries during the moment of impact.

Furthermore, the extra-large belay loops will move the wearer's buttock in line with the lanyard's vertical force plane, effectively moving any fall arrest hardware away from the face and reducing the likelihood of head injuries.

The Australian Standard (AS/NZS 1891.1) states that a fall arrest harness must have a central front attachment point, however many harnesses have an attachment point that is positioned left of centre in disconcerting contravention of the Standard in spite of third party accreditation



WHAT TO LOOK FOR BEYOND AUSTRALIAN / NZ STANDARD REQUIREMENTS

- Closed loop rear attachment point (as opposed to a floating rear dee).
- Central front attachment point as per Australian Standards (must not be left of centre). Preferably in co-joined Belay Loop configuration
- Extra-large front belay loops to keep fall arrest hardware away from the head at Moment of Impact (MOI).
- Padding between the buckles and the wearer's body to reduce hardware bruising during the Moment of Impact (MOI)
- Retro-reflective webbing for enhanced low light wearer visibility to aid rescue
- The SAI Global 5 Ticks Logo showing independent Certification to Australian Standards.

Certified Product
Australian Standard
AS/NZS 1891.1:2007
Lic:21481
SAI Global

Lanyards

The lanyard is a critical component of the fall arrest system and principally responsible for absorbing the energy of the fall by dampening the forces transferred to the body at the Moment of Impact.

Australian Standards require that that forces applied to either the central front or rear anchor point during a fall of two metres does not exceed 6kN over any one period of 50ms (that is, the deceleration is limited to 6g) in which case the Standard states that "this level of deceleration is readily survivable provided the person suffering the fall is properly constrained in a harness".[4]

However, like harnesses, there can be huge differences in the properties of lanyards that meet Australian Standards.

In fact the Australian Standard does imply allowance for maximum forces to exceed 6kN at any one point as long as the average force over 50ms does not exceed it.

This is particularly noteworthy when evaluating the suitability of American-designed lanyards where their OSHA regulations limit maximum forces at any point to 8kN.

While these lanyards may meet the Australian standard of 6kN when forces are averaged out, the maximum force applied to the body during the moment of impact will be far more significant than an Australian-designed lanyard.

LINQ LANYARD TESTING:

Facts and Figures

The Australian-designed LINQ lanyard is engineered, regularly tested and proven to limit maximum stopping forces on 100kg in a 3.8m freefall to less than 4.8kN, resulting in industry-leading figures.

Furthermore, testing on a 128kg individual in a 3.8m freefall shows LINQ lanyards limit maximum forces to under 5.6kN.

Furthermore, eight independent batch tests conducted on LINQ lanyards on four separate occasions in 2015 found they limit 100kg, 3.8m free fall average stopping forces over 50ms to an average of 3.76kN, nearly 40% less than the Australian Standard requires.

Furthermore, eight drop tests found peak stopping forces averaged 4.257kN – see table below.

The difference between a maximum force during the moment of impact of potentially greater than 7kN and a maximum force of around 4.25kN is significant and could mean the difference between a serious injury and walking away unharmed.

Serial Number	Day of Month	Stock Code	Maximum Load	50m/s Ave Load
62189	May-15	WLE2SNSD	4.367	4.040
62844	Jun-15	WL01SNSN	4.330	4.110
62845	Jun-15	WL01SNSD	4.325	4.070
633349	Jun-15	WL01SNSN	4.400	3.820
64420	Aug-15	WL01SNSN	3.815	3.500
64931	Sep-15	WL02SNSN	5.114	3.850
65435	Sep-15	WL01SNSN	4.058	3.520
65657	Sep-15	WL01SNSN	3.648	3.170
Average over 8 tests:			4.257	3.760

MINIMISING FALL DISTANCES:

Other methods of limiting the force applied to the body during the moment of impact should include ensuring a minimum of slack in the fall-arrest lanyard between the user and the attachment.

This can be aided by ensuring the anchor point location sits as high as possible in relation to the harness fall arrest attachment point and avoiding work above that anchor point, as this will increase the free fall distance in the event of a fall, resulting in higher forces on the body and the increased likelihood of the lanyard snagging on obstructions. (3)

Suspension Trauma

In the event of a fall from height, the danger does not end after a lanyard's deployment and the user's safe fall arrest.

Hanging stationary in a harness can also cause death as a result of orthostatic intolerance, commonly known as suspension trauma.

This is caused by the tourniquet effect of the harness combined with the inaction of the leg muscles and the force of gravity all limiting the ability of the heart to pump blood from the legs back to the body's vital organs resulting in a condition known as venous pooling, and presents with conditions similar to compression injury.

Initial symptoms of suspension trauma are tingling or numbness in the legs, nausea, dizziness, sweating, heart palpitations and confusion. Fainting occurs next, which, in a harness, will serve to exacerbate the suspension trauma by eliminating movement altogether while still keeping the subject upright. Research has found that after losing consciousness while suspended in a harness, brain damage and death can in extreme cases occur within four to six minutes.[5]

Even if a climber or worker is rescued alive in their harness after suffering orthostatic intolerance, they are still in grave danger due to the large amount of deoxygenated blood in their legs that may cause a heart attack or kidney failure when it returns to the body's vital organs. Research by Flora and Holzl found that of eight rock climbers who were alive after hanging in a harness from periods of half an hour up to eight hours, all died after they were rescued, surviving from half an hour to 11 days.[6]

While each individual's tolerance to suspension varies, everyone is susceptible meaning that using a harness designed to enable blood flow in the event of prolonged suspension is critical, as is their quick rescue and recovery.

Safe Work Australia states that the condition may be worsened by heat and dehydration and that a suspension trauma strap or a 'foothold strap' should be provided to enable the worker to place weight on their legs when suspension is longer than five minutes.[3]

The 'Standing Step Harness' provided as standard in LINQ Tactician and Elite harnesses eliminates the tourniquet effect of the harness and allows the wearer to stand and stimulate the muscles that pump blood back to the body's vital organs. The resulting increased blood flow reduces the risk of suspension trauma and associated dangers.

PREVENTING SUSPENSION TRAUMA[3]

- Train workers on the dangers of suspension trauma.
- Workers should never use a harness alone.
- Train workers on expedited recovery procedures
  and onsite rescue equipment.
- Establish emergency and rescue procedures in the event of a fall.

If Suspended Ensure

- The rescue begins immediately.
- The worker deploys and uses a suspension trauma strap.
- They move their legs and push against any footholds where possible.
- They raise their legs and get them as horizontal with head as possible.
- Other workers should not put themselves at risk during the rescue.

Equipment Inspection and Maintenance

The Australian Standard requires that harnesses and lanyards must be inspected by a height safety equipment inspector as per the manufacturer's instructions, or every six months.[7]

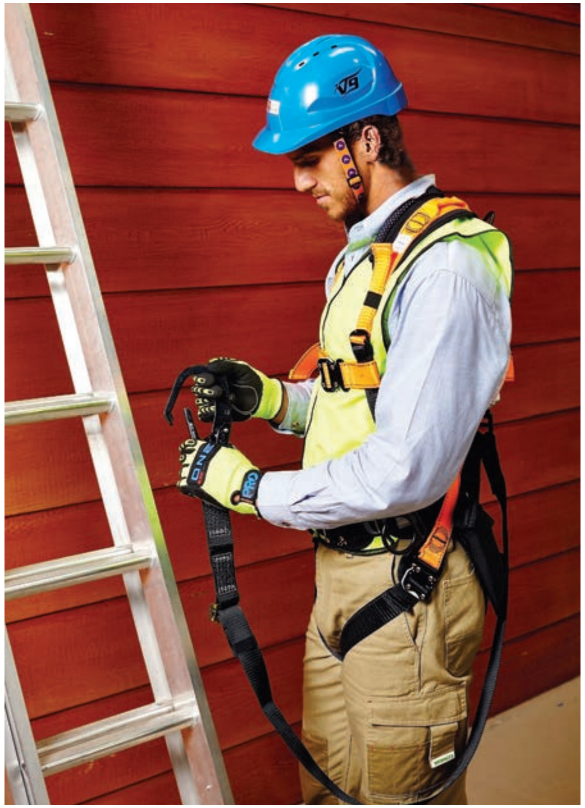
Furthermore, the manufacturer and/or supplier of the equipment should be consulted for any product-specific requirements.[3]

Prior to and after use, fall arrest equipment including lanyards and harnesses must be inspected by a 'competent person' – being one who has appropriate training knowledge and experience.[7]

Users of height safety equipment should also ensure that any equipment is in good condition and order and has been inspected, serviced and maintained.[7]

Equipment which is defective - or where there is any doubt - must not be used and must be either destroyed or marked 'defective' and repaired in accordance with manufacturer's instructions.

If a piece of fall arrest equipment has been used to arrest a fall it must be withdrawn from service immediately and a replacement obtained if necessary.[7]



Summary

Falls from heights are the leading cause of death in construction and in 2010-11 resulted in 7730 claims for serious injury (21 every day) across all industries.

Many of the deaths and injuries resulted from the worker hitting the ground meaning using fall arrest equipment is an obvious decision.

However injuries can also be caused during the Moment of Impact (MOI) as a result of poorly fitted or designed harnesses.

Despite Australian Standards stating a harness must have a 'central' frontal attachment point, many certified harnesses have an attachment point that is left of centre which can lead to vectorial (diagonal) forces during the moment of impact.

Other harness design features, or lack thereof, significantly influence how much force is applied to the body during the moment of impact and where that force is applied. Quality harness design and fit can mean the difference between serious injury and walking away unharmed. Resultantly, these design parameters must be fully understood.

Further contributing to injuries are large variances in certified lanyards' ability to absorb stopping forces, with American-designed lanyards transmitting up to 3kN more force through the body than LINQ lanyards due to differences in the American and Australian Standard requirements.

The dangers do not end after the fall arrest. Suspension trauma is potentially deadly and Safe Work Australia recommends harnesses contain a mitigation device such as LINQ's Standing Step Strap.

All fall arrest equipment should be regularly maintained and inspected by quality personnel and/or licensed inspectors and staff trained on its use as part of broader training on safely working at heights.

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