Load securing in the log transport industry – Injury risks and interventions

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Structure of this report

This report is structured to emphasise the key points and recommendations that industry need from this study. After a very brief introduction to the study and its aims (Section 1), Section 2 focuses on the key information that identifies the injury risks associated with load securing (throwing chains and chain tensioning). The key findings of this study can be found on page 10. This is followed by possible interventions that have been identified in the study (Section 3). The final section (Section 4) provides all the background material that may be needed by anyone seeking further evidence for the key points identified in Sections 2 and 3.

Executive Summary

- The log transport industry has become increasingly concerned about truck driver injuries as a result of load securing activities. This is particularly since 2004 following the introduction of 22m rig configurations with an increased number of log packets and therefore a greater number of chains. Further, new High Productivity Motor Vehicles (HPMVs) with higher load weights may also increase chaining requirements in some instances.
- Long-term shoulder pain associated with chain throwing has been identified as a particular problem. Load tensioning using twitches has also been linked to injuries, especially blunt injuries including the loss of eyes and other facial injuries.
- This study describes load securing tasks in detail and provides an evaluation of injury risk associated primarily with chain throwing but also with chain tensioning.
- The study involved a range of methods which included: collection and review of literature and other background information; development of injury risk factor models; a survey of drivers and managers; and the conducting of case studies for a sample of log truck drivers.
- Case study methods included use of biomechanics and postural analysis tools, along with collection of subjective and objective data.

- The literature indicates that throwing activities are associated with injuries, and in particular shoulder injuries, and that exposure and technique may both play a part.
- Well over a third of those surveyed in this study reported that they had been injured while throwing chains. These injuries were largely sprain/strain type injuries, of the shoulder as well as neck, lower back, arms, and knees. These types of injuries are also known as Discomfort, Pain, Injury (DPI, the term used by ACC), Repetitive Strain Injuries (RSI), Occupational Overuse Injuries (OOS) or Musculoskeletal Disorders (MSD). The survey was a 'snapshot' in time and over their working life, a greater proportion of drivers may experience these injuries.

- Limited reporting may mean the proportion of injured drivers could be higher; reporting of all injuries and in particular musculoskeletal injuries should be encouraged to better inform industry of the issues.
- The Log Transport Safety Council is already taking steps to alert drivers of the risks of injury associated with twitching in particular, such as through a 'Hazard Alert' published in LTSC newsletters and on the LTSC website (see www.logtruck.co.nz). Alerts to these risks are also reinforced by some operators.
- Any interventions require sufficient planning, trialling, driver input and proper consideration to ensure they are effective and also do not lead to other inadvertent hazards.
- The most effective way of addressing injury risk, especially cumulative type disorders, is to implement a range of changes that address contributory risk factors.

The cumulative evidence of this study suggests that both chain throwing and chain tensioning have significant injury risks associated with them, and a large proportion of drivers are likely to be affected in some way over the course of their working life. The extent of these issues is likely to widen in the future as the driver workforce ages further.

A range of interventions have been suggested. Key interventions to consider in the short to mid-term include:

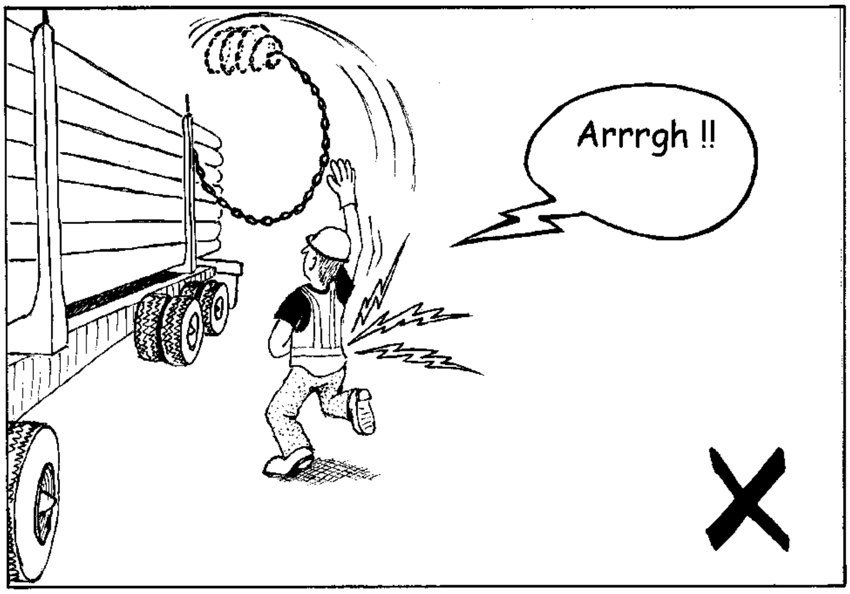
- Better provision - during skid site design and preparation - for incorporating a specific flat, non-sloping and sufficiently spacious area for chaining up
- Exploring the use of loaders to place chains over the load
- Reducing chain weight by increasing the use of wire cable and chain combinations
- Ensuring targeted training takes place, which includes providing specific principles for reducing injury risk
- Explore modified twitch designs to reduce injury risk

In parallel with this study, alternative log load securing methods are being trialled by the Log Transport Safety Council, which in the longer-term, may remove or significantly reduce the need for the activities that are associated with load securing injuries.

Following a workshop with LTSC representatives, two key initiatives have been selected for immediate development:

1. Exploring the use of loaders to place chains over the load
2. Explore modified twitch designs to reduce injury risk

The suggested steps for evaluating these initiatives are outlined in Section 3.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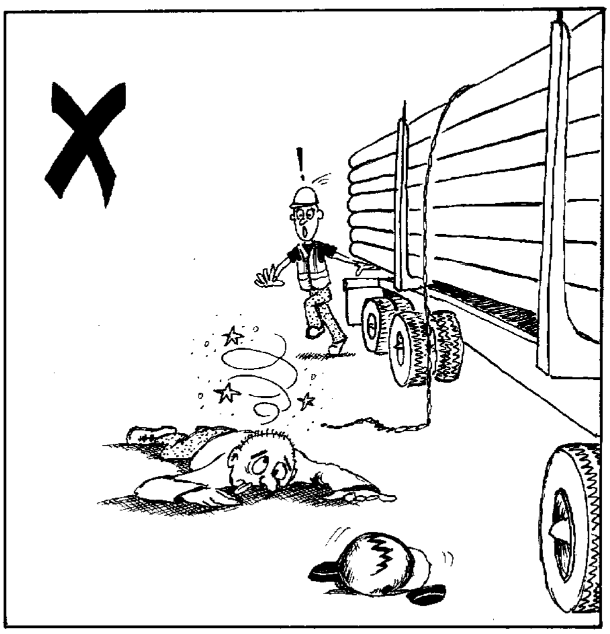

Section 1: Introduction and research approach

Problem and aims

- Within current log-transport operations in New Zealand, throwing chains and tensioning them via twitches or winches is an activity that all log truck drivers must carry out following loading.
- The log transport industry has become increasingly concerned about the injuries that truck drivers are having as a result of load securing activities. Chain throwing has been implicated with long-term shoulder pain and load tensioning using twitches is related to periodic incidence of blunt injuries including the loss of eyes and other facial injuries.
- An aging driver workforce may contribute to the risk of these injuries. Over time the load securing task that is required of drivers may be relatively more demanding as the physical capability of drivers reduces through age.
- This report has implications for load securing devices, practices and regulations, and supports a parallel investigation of load securing requirements which is being conducted by the Log Transport Safety Council.

The aim of this report is to:

1) Fully describe the load securing activities and the context in which the tasks are conducted, including variations of throwing and securing that currently exist
2) Evaluate the severity/risk of chain throwing and load securing with respect to injury risk and drivers' physical capability – in the short term as well as long term discomfort, pain and injury
3) Recommend a range of intervention approaches, including a review of load securing and capturing current industry initiatives in this area.

The load securing tasks

For the purpose of this report, load securing activities can be divided into two main activities:

1. Chain throwing: Throwing chains over the logs so that the loose end of the chain can be retrieved on the other side of the load.
2. Chain tensioning: Using twitches or winches (usually with an extension bar) to adequately tighten the chains and therefore secure the load.

Research approach

The data collection and analysis approach used for this project are outlined in Table 1 below:

Table 1. Research stages

Method	Description
Background information and literature review	• Previous LTSC / TERNZ studies (e.g. The health and fitness of Log Truck drivers) • Preliminary skid site visit (near Rotorua) and discussion with industry members • Review of literature related to transport and truck injuries, injury mechanisms and methods for evaluating injury risk • Background information on the shoulder joint as a particular area of focus *Note: This information is presented in Section 4*
Injury risk factor model	Qualitative injury risk factor models were developed separately for chain throwing and chain tensioning to identify the various direct and indirect factors that may contribute to the risk of injury via these tasks. This provides a framework for more specific evidence that contributes to an understanding of the magnitude of risk associated with each task.
Driver survey	A driver survey was used to understand the risk associated with chain throwing and chain tensioning, the types of injuries that are likely to result from these activities, the difficulty of carrying out these tasks and suggestions for improving safety.
Management survey	A similar survey was carried out for management staff, with more focus given to understanding the importance of chain throwing and tensioning injuries and the factors that are likely to be associated with them.
Case studies	Objective data from (convenience) sample of drivers at Kaiangaroa Processing Plant (KPP) and bush skid sites near Tokoroa. Measures included: • task dimensions and measures • biomechanical (body position, technique and force) measures from video and chain weights • postural analyses • subjective data
Interventions for action	Based on knowledge from the industry and information gathered within this study, a number of task, worksite and organisational interventions are proposed.

Section 2: Injury risk for chain throwing and tensioning

Mechanisms for injury

Injury risk occurs when task demands are too great relative to the capabilities of the human body. Discomfort, pain and injury can happen suddenly or occur gradually over time. Two types of injury that are common while throwing or securing chains are ‘struck by’ injuries where someone is hit by an object (e.g. twitch bar) and strain/sprain type injuries sometimes known as musculoskeletal or overuse disorders. Both types of injury will result from a number of factors and identifying these will help to prevent them.

Shoulder injuries: A key area of concern for industry

- Although severe sudden injuries from twitching are a concern for the log transport sector, shoulder injuries from chain throwing may have the most significant impact in terms of the number of drivers who sustain these injuries and the potential for a long-term effect on a driver’s ability to carry out their job. For this reason, it is useful to understand why the shoulder is particularly prone to injury.
- Three bones form the shoulder area, or shoulder girdle: the collar bone (clavicle), the shoulder blade (scapula) and the upper arm bone (humerus). The shoulder area consists of several joints connecting the upper limbs to the rest of the skeleton, which combined provide a large range of movement. Three key muscles (rotator cuff) hold the ball and socket joint together during movement and when there is a load on the arm.

Figure 1. Shoulder anatomy - bones (seen from the front) and rotator cuff muscles (seen from behind) of the shoulder joint

- The shoulder joint is vulnerable to injury as it relies heavily on the surrounding muscles for its stability; it is particularly prone to injury when the arm is above horizontal and under resistance (such as when throwing chains over logs). A common injury in this situation is a pinching or tear of one of the rotator cuff muscles.

Models for chain throwing and chain tensioning injury risk

Two diagrammatic models (one each for chain throwing and chain tensioning) are presented to demonstrate the wide range of factors that may contribute to injury risk (Figure 2Figure 3). Only some of the more direct factors are included in the models. Other factors including wider environmental, organisation and industry influences are just as important and also need to be identified, as they in turn will determine, cause or affect the factors shown in the diagrams.

For chain throwing, there are a number of techniques that can be employed. These include:

- The ‘skipping rope’ technique
- The ‘flick’
- The ‘cricket bowl’ overhead technique
- Standard chain throw

At some large facilities such as at the KPP, the skipping rope technique is useful as it requires much less effort, but also requires at least 5m of space between the driver and the truck or trailer. However, because most chaining takes place in a bush setting, in constrained conditions, most drivers are limited to some variation of the standard throwing technique.

Conclusions from background literature

The literature indicates that throwing activities are associated with injuries, and in particular shoulder injuries, and that exposure and technique may both play a part.

Literature about workplace risk factors indicates there are wide ranging contributory factors, including physical (force, repetition, wide ranges of shoulder movement etc) but extending to psychosocial factors such as workpace, stress, along with duration and other issues such as the impact of older workers who may take more time to recover from injury.

Tools for evaluation of injury risk identified include: assessing biomechanics, torque, range of movement and deviated postures; self-report, surveys and interviews for subjective data; and observational techniques such as RULA and REBA are well used and established.

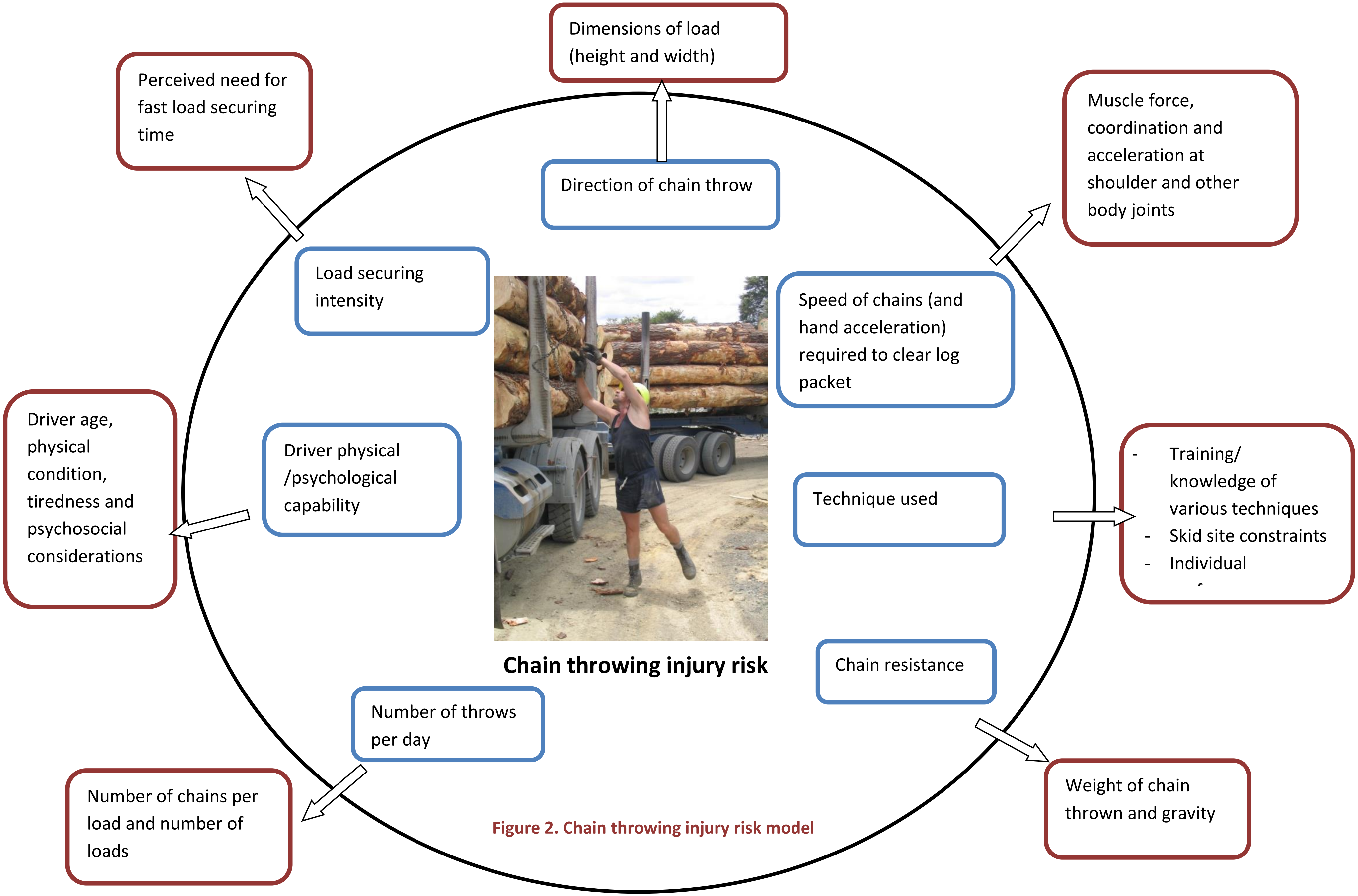

Figure 2. Chain throwing injury risk model

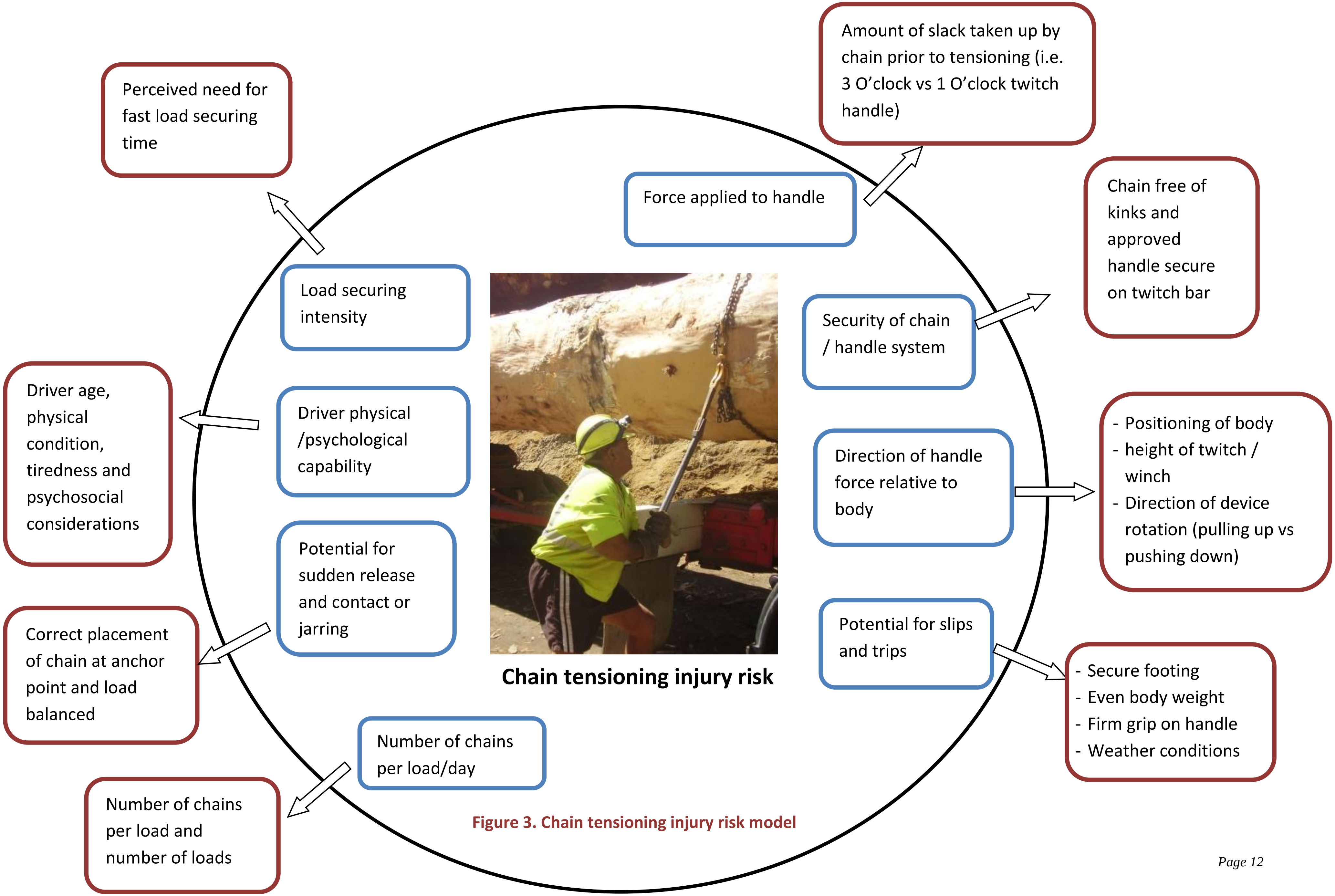

Figure 3. Chain tensioning injury risk model

Summary of study results

A range of methods were used to evaluate the risk of injury from chain throwing and tensioning. Table 2 and Table 3 summarise the key findings from each analysis; more extensive results are outlined in Section 4 (page 22). More information about methods used can be found in Section 4 (page 20).

Table 2. Risk of injury from *chain throwing*

Method used	Key finding
Biomechanical analysis	High peak shoulder torque of around 60 N.m, with shoulder in a relatively unstable/injury prone position.
REBA postural tool	Risk level Medium to High; interventions "recommended soon"
RPE (Rating of Perceived Exertion) Scores (out of 10) – whole task	Scores between "Moderate" (3) to "Very Hard (maximal)" (9). Average score "Hard" (5)
Survey feedback	38% of drivers reported injuries, primarily strain or sprain of the shoulder joint

Table 3 Risk of injury from *chain tensioning*

Method used	Key finding
Biomechanical analysis	n/a – visual inspection of postures when applying force to twitch bar suggests some problematic postures in some instances (e.g. high shoulder with significant load)
REBA postural tool	Risk level Medium to Very High; interventions "recommended now". Higher scores for twitches than winches
RPE (Rating of Perceived Exertion) Scores (out of 10) – whole task	Score between Moderate (3) to Very Hard (maximal) (9). Average score Hard (5)
Survey feedback	35% of drivers reported injuries, a mixture of strains and sprains, and "struck by" bruises and lacerations

n/a: The quantitative biomechanical analysis was only completed for the throwing activity as it is most likely to be associated with longer-term 'overuse' type injuries, compared with chain tensioning where risk factors associated with sudden 'struck by' injuries appear to be more important.

Overall, the cumulative evidence of the analyses suggests that both chain throwing and chain tensioning have significant injury risks associated with them. While some drivers seem to have no problems with throwing and tensioning chains, a significant proportion of drivers are likely to be affected in some way, especially given the age profile of log truck drivers in NZ. The extent of these issues may widen in the future as the driver workforce ages further.

Section 3: Interventions to reduce injury risk

- A range of interventions are outlined – these are not intended to be prescriptive but rather provide ideas for consideration. Any intervention being considered should be prioritised, planned, trialled and implemented in a structured manner. All interventions would need more exploration to determine their effect and to ensure new hazards are not being introduced.
- The interventions are derived from published literature, overseas practice, survey results, case studies (objective and subjective data), additional comment and feedback from managers and drivers, and input from the authors of this report.
- As demonstrated in Figure 2 and Figure 3, no single factor is the cause of injury risk; and as such considering and implementing a number of factors is the most effective way of reducing injury. In practice, some elements could be implemented easily; others may take further investigation or require more planning, time or a greater cost.
- Table 4 summarises the suggested interventions which include those that affect the chain throwing task, chain tensioning or both; they are therefore grouped according to intervention category rather than priority or task. However, within each category, an attempt has been made to order interventions according to their potential effectiveness. Detailed prioritising would be needed through industry representatives. Further detail about each intervention is provided in Table 4, including whether it addresses chain throwing, tensioning or both tasks.

Table 4. Summary of interventions suggested at different levels

Category	Intervention description
Organisational design	1. Plan for and provide specific a chaining up area on skid site 2. Reduce time pressure and working hours 3. Implement an effective maintenance programme 4. Implement an early reporting and injury management system
Physical task design	5. Use loader drivers to place chains over load 6. Reduce chain weights 7. Use auto tensioning devices 8. Use alternative load chain tensioning methods 9. Explore modified twitch design 10. Attach and throw rope (leader rope) to pull chain over 11. Use ramp to reduce throw height 12. Place anchor points at appropriate heights 13. Install winches to replace twitches 14. Limit excessive load heights 15. Use locking device for winches and twitches 16. Provide or develop tension measuring device for drivers
Technique and training	17. Specific task training principles 18. Communicate effectively with loader driver

The key interventions to consider in the short to mid-term include:

- Better provision - during skid site design and preparation - for incorporating a specific flat, non-sloping and sufficiently spacious area for chaining up (1)
- Exploring the use of loaders to place chains over the load (5)
- Reducing chain weight by increasing the use of wire cable and chain combinations (6)
- Ensuring targeted training takes place, which includes providing specific principles for reducing injury risk (17)
- Explore modified twitch designs to reduce the injury risk (9)

Following a workshop with LTSC representatives, two key initiatives have been selected for immediate development:

1. Exploring the use of loaders to place chains over the load
2. Explore modified twitch designs to reduce injury risk

The following steps are recommended for these initiatives:

1. Explore modified twitch designs to reduce injury risk:

- Analysis of factors contributing to previous twitch injuries including driver/H&S personnel interviews to establish key risk factors
- Suggest twitch re-design criteria (e.g. Length of lever, force required to secure etc) and compare with existing LTSC ideas
- Mock up re-designed twitch, isolated trials and then field trials.
- Evaluate function of newly designed twitch by comparing video footage of old and new twitch and interviewing users. Identify any injury risks that may have been introduced by the new design and check that the new design represents an improvement
- Production if successful, further modifications if needed.

2. Exploring the use of loaders to place chains over the load

- Set-up field trials to evaluate feasibility
- Use video and interviews to understand the advantages and disadvantages of this method, from both the truck and loader driver's perspective

Table 5. Details for interventions suggested at different levels. Note: The last column notes whether they are relevant to chain throwing, chain tensioning, or both

	Intervention description	Evidence and purpose of intervention	Steps required Possible barriers or disadvantages to intervention	Task[1]
1	Provide a specific area for chaining up; flat ground of sufficient size, should be planned for at an early skid site development stage (Organisational design)	Reduce injury risk from hazards and distractions Flat ground and space allows easier throwing and more choice of technique Reduces the increased risk resulting from throwing uphill on sloping ground Include sufficient room to stand up to 5m from truck for throwing Could mound up a ramped area to reduce throwing height requirement, especially where skid site is to be used for a long period of time	Need to incorporate into early management plans Account for cost and time Explore potential for ramped area by testing with drivers Industry resistance/culture, adapting to change	Throw Ch Ten
2	Reduce time pressure and working hours (Organisational design)	Fatigue and stress are known contributors to injury. Production and time pressure adds to injury risk, especially at skid sites where a number of factors contributing to injury risk already exist (including other trucks and vehicles, availability and workload or loader driver etc)	Truck driver working hours are extrinsically linked to forest industry pressures and systems Wider industry needs to be aware of the risk posed by long truck driver working hours so that there is more incentive for more favourable scheduling for drivers	Throw Ch Ten
3	Ensure maintenance systems for all chain tensioning equipment (Organisational design)	Reduce risk of ‘struck by’ events e.g. from worn teeth on winches; twitches checked and replaced as needed	Cost Industry culture/buy in	Ch Ten
4	Early reporting and injury management (Organisational design)	Drivers tend not to report injuries. Good reporting provides insight into task factors. A well organised injury management and early reporting system can help reduce incident severity and reoccurrence.	Musculoskeletal injuries are hard to manage due to the range of contributory factors. Industry resistance to change where results not easy to demonstrate in the short term.	Throw Ch Ten

[1] Throw = chain throwing Ch Ten = chain tensioning

5	Loaders place chains over load (Physical task design)	Removes the need for drivers to throw chains Using this method elsewhere (e.g. in Norway) Some loader drivers do this currently, for example for female truck drivers	Access for loader/height of load Communication between loader operator and driver Culture, industry resistance and achieving change in practice. Needs trialing	Throw
6	Reduce weight of chains: - Lighter chains - Chain and wire combination - Standardising chain length and weight as much as possible - Lighter chain or strapping with same strength characteristics – eg titanium, other materials (Physical task design)	Reduce force by reducing weight. Only throw required length for specific load Belly chains longer, heavier – replace portion of chain with wire rope Identified more than any other intervention by drivers and managers Reduce exposure /frequency by reducing number of chains (if other materials used)	Need to explore alternative materials and establish effectiveness of chain tensioning Need to determine feasibility of increasing the use of lighter rope or half wire strops Address issue of storing (coiling) wire rope so can be used more readily Explore standard chain lengths so excess chain not used	Throw
7	Auto-tightening / auto tension device (Physical task design)	Used elsewhere internationally[2]	Cost; What is available Need to research internationally and trial in NZ	Throw Ch Ten
8	Secure the load using alternative methods[3] (Physical task design)	Remove or reduce exposure by reducing the need for drivers to throw chains May also reduce use of twitches and associated risk	Need to identify and establish effectiveness of method, trial and implement	Throw Ch Ten
9	Explore modified twitch design (Physical task design)	Might be able to reduce risk of 'struck by' injuries with altered design	Need to fully explore; identify contributing factors of previous injuries through accident analysis and examine potential design changes.	Ch Ten

[2] Item 6: See example http://www.tractiontech.ca//news.php?ref=6044
[3] Item 5: Refer to associated report by Engistics "Logging Load Restraint Review" 19/04/2011

10	Use 'leader' rope on end of chain to throw over and then pull chain over from other side (Physical task design)	Reduces force if throwing lighter rope Some drivers already use this technique	Only force reduced but same frequency and duration Possible increase in work pressure due to extra time required. Resistance due to macho industry culture	Throw
11	A platform (or mound, ramp) to stand on to reduce throwing height, if carting from one site with a lot of trucks (Physical task design)	Removes or reduces a number of contributing factors Alters throwing height, angle and effort needed to throw chains	Only feasible at some locations. Would need to explore design and cost Industry resistance/culture	Throw Ch Ten
12	Appropriate height of chain anchor point to allow appropriate throwing angle and technique. (Physical task design)	Can use skip or flick technique when anchor points high enough (i.e. on bolster, but not when on chassis) Allows selection of technique for individual	Belly chain by necessity attached to chassis Have not established optimum height, would need to determine by examining in more detail	Throw
13	Install winches on all new trucks; put in place a structured programme for installing winches on current stock (Physical task design)	Reduces hazard of 'struck by' events as winches designed to not flick up. Most frequently identified by drivers and managers for reducing chain tensioning risk Winches produced more favourable values for difficulty of use (survey) and for postural observation (case studies)	Cost of implementation Not fully removing risk	Ch Ten
14	Limit excessive height loads (Physical task design)	Manually throwing chains over off highway loads in particular results in high forces and shoulder ranges of movement. Where loads are high risks need to be addressed by the other described methods – providing flat areas, ramps, reducing chain weights etc – and where possible remove the risk by using the loader to place the chains over	Load height determined by log characteristics, supply requirements etc Truck design, load stability	Throw
15	Design and trial a device to lock over winch/twitch, so it cannot flick up (Physical task design)	Suggested by manager	Need to explore, see if used elsewhere and trial Cost	Ch Ten

16	Provide drivers with means of determining and demonstrating that load has sufficient tension (Physical task design)	Explore methods for drivers to establish that sufficient tension has been applied to reduce use of excessive force on securing the load Many drivers describe how some drivers apply more force than is required. Also that Police stops are subjective in their assessment of chain tension	Method/device needs to be explored, and trialled followed by relevant education. Chain tension measurement tool could be used for training purposes May have industry resistance, perceived as not accurate or necessary	Ch Ten
17	Specific training to provide drivers with knowledge about risks and different means of management. Consider age, fitness and ability (Technique and training)	Techniques used by drivers can impact risk depending on factors like their physique and specific conditions (chain length, ground, weather etc). Sufficient knowledge and training can allow drivers to adjust techniques accordingly. Individuals might find different techniques preferable; but key hazards and principles still need to be taught. Some specific examples identified include: - Minimising large and end of range joint movements, - Use momentum and big muscle groups as opposed to restricting movements to the shoulder - Avoid jarring and forceful actions - Drivers should move to a better location for chaining up if area is sloping, cramped, muddy, uneven etc - Drivers need guidance on the degree of tensioning required. A '3oclock' bar position and lower reduces the shoulder range of movement required - Ensure the chain is sitting correctly at anchor point, and not able to 'give' suddenly when tension started - Ensure workers are informed about injury risk and health and fitness and how it may influence their ability to manage task conditions. Training should include education about warm-up and general health, adequate hydration and nutrition etc	Appropriate trainers – experienced or skilful drivers are not necessarily the best teachers Training and altering technique does not reduce force, frequency or other hazards nor addresses organisational and other contextual factors that comprise risk of injury. Difficult to establish whether tension sufficient, and to convey to drivers and to police Could explore use of tool for measuring tension Industry resistance/culture – assumption of adequate knowledge and training More consideration would need to be given to specifying training content	Throw Ch Ten
18	Communicate effectively with the loader driver during loading (Technique and training)	Careful loading can reduce the amount of movement of logs as loads are tightened, hence reducing the chance of sudden jarring or 'giving' of logs, which can cause injury. Also can influence load height.	Dependent on individual driver and loader operator Use industry communication methods to help	Thr CT

Section 4 Background information, literature, and detailed study results

This section outlines the findings from the background information, literature search, and detailed results from subsequent fieldwork and data collection:

- Detailed study results:
  - Chain throwing: survey, case studies (biomechanics, REBA, physical task characteristics, RPE)
  - Chain tensioning: survey, case studies (REBA, physical task characteristics, RPE)
  - Discussion
- Load Securing and risk of injury:
  - Problems and aims;
  - Log truck load securing requirements;
  - Chain throwing and tensioning
- Brief literature review
  - Injury literature associated with transport and trucks
  - Shoulder injury mechanisms
  - Methods for evaluating risk of injury
  - Conclusions from background literature review
  - References

Detailed study results - Chain throwing

Survey

A survey was distributed by email and via LTSC representatives to managers / operators and drivers, and conducted verbally with case study drivers. The survey included questions about individual details and log truck driving experience, and opinion and experience regarding load securing methods. The survey directed at managers also requested information from the company about injuries associated with load tensioning and chain throwing for a 12 month period. The survey directed at drivers requested information about injuries they may have had associated with these tasks and also collected data on their height and weight, to use in conjunction with task dimensional data.

	Drivers (n= 42)	Managers (n= 8)
Experience as a driver	Av 14 yrs Range 3 m to 40 yrs	Av 17 yrs Range 0 to 48 yrs

	Drivers (n= 42)
Age	Av 49yrs; range 24 to 65 yrs
Ht	Av 178cm; range 163 to 190cm
Wt	Av 103kg; range 61 to 140kg

- 16 of the 42 drivers reported having injuries associated with chain throwing activities.
- All were strain/sprain muscular or joint type pain, involving one or more parts of the body including shoulders, neck, back, arms, wrists, knees.
- Injuries ranged from unreported aches and pains to injuries requiring treatment and involving up to 7 ½ months lost time.
- Few companies provided data regarding reported injuries. Of six reported chain throwing injuries, five were strain/sprain or other musculoskeletal disorders; four required treatment and three resulted in between 3 and 7 months lost time.
- Drivers rated the difficulty of chain throwing on a scale of 1 (very easy) to 5 (very difficult). Their average score was 2.3, ranging from 1 to 5.
- Most managers viewed the issue of chain throwing as important and rated chain throwing an average score of 3.3, ranging from 2 to 5.
- Managers tended to supply more detail on factors contributing to injury risk, outlining organisational and environmental conditions as well as task elements such as chain weight and frequency. Subjective feedback from managers and drivers contributes to the models outlined in section 1.

Case studies

Eight drivers were observed securing loads at KPP; data collected included video and photographic footage, physical workplace measurements, subjective information. A further two drivers were observed at a skid site to provide further insight into the context in which task occurring.

Age	Average age 50 yrs; ranging from 34 yrs to 65 years old
Height (stature)	Average height 182cm; ranging from 168cm to 190cm
Weight	Average weight 103.6kg; ranging from 85kg to 140kg
Experience	Total experience as a driver Average 18 yrs; ranging from 3 yrs to 40 years
Previous injury throwing chains	Four drivers have had throwing injuries; all were strain/sprain type injuries, resulting in a total of approximately 10 months lost time
Previous injury tensioning/securing load	Four drivers have had tensioning injuries; three were bruises or lacerations from a contact injury, one a strain/sprain injury; none resulted in lost time

Biomechanics analysis

The following biomechanics analysis of chain throwing demonstrates the movements and forces required to throw chains.

Figure 4. Chain throwing action

Figure 4 shows that the driver must accelerate his hand so that the chain leaving it has sufficient velocity (including the correct direction) to travel over the packet of logs. This requires the driver to apply forces in the muscles of various parts of the body, starting with the legs and trunk.

The shoulder joint should help most in the later part of the technique, adding to the movement started by the legs and trunk. As in other activities such as rowing or a discus throw, this sequencing of large muscles first followed by smaller muscles of the limb at the right time is very important, both for performance and injury prevention.

Using video analysis and estimates for chain weight (estimate of 5 kg – a relatively high but not unusual weight), it is estimated that peak shoulder torque for chain throwing may be in the order of 60 N.m (or the equivalent of holding a 10 kg weight still with a horizontally outstretched arm). This represents a relatively high torque at the shoulder. As a comparison, professional baseball pitchers achieve shoulder torques of approximately 100 N.m for a similar shoulder movement (but then such athletes are typically younger, train and prepare extensively, have lots of support and still injure themselves from time to time).

Figure 5. Start and end postures throwing a chain

The shoulder joint does not do all the work and as can be seen in Figure 5, the legs, hips and truck also contributes to throwing the chain. In fact, the more a driver can use the larger muscle groups to generate the force needed to get the chain over the logs the better, as this will reduce the demands on the shoulder joint, which is more susceptible to injury in this situation. However, this may be more difficult for older drivers who may have restricted mobility in some joints.

The observed technique of chain throwing among the drivers, suggests that many of them are giving a relatively high degree of exertion in order for the chains to clear the logs.

This is consistent with the reported effort required to throw chains. Hamish Mackie (one of the authors of this report, 1.91m, 100 kg) attempted to throw chain over a packet of logs on a truck in order to gauge the intensity of the activity. After two attempts with the chain landing on the top of the logs (and some subsequent technique tuition from the truck driver), he successfully cleared the logs with the chain. Although his technique was probably less than perfect, he estimated that it required approximately 90% of maximal effort to successfully throw the chain.

A conversation with an orthopaedic surgeon, who specialises in shoulder and elbow injuries, concluded that chain throwing could pose a risk for shoulder injury, particularly if the weight of the chain is too high. Minimising the weight of the chain (or using a leader rope) was suggested as one simple solution to prevent shoulder injuries.

Postural analysis tool - REBA

A postural analysis tool –Rapid Entire Body Assessment (REBA) was applied to a selection of observed postures, one or two for each task per subject, providing an assessment of the postures of the body along with muscle function and the external loads experienced by the body. As the analysis takes one or two sample postures for each activity, it does not account for the full range of possible postures or for the other factors contributing to injury risk. However, the REBA action levels provide an indication of level of urgency about the need to change how a person is working as a function of the degree of injury risk.

REBA Score	Risk Level	Action
1	Negligable	None necessary
2-3	Low	May be necessary
4-7	Medium	Necessary
8-10	High	Necessary soon
11-15	Very High	Necessary now

From the selected snapshot postures, taken at the beginning, during or end of throwing actions, the average REBA score was 8, indicating a high level of risk requiring some sort of intervention. It must be emphasised that the task will also include postures likely to be less harmful, and that these observations do not account for duration and frequency, or the other contributory factors. However it does provide an indication that the throwing task results in postures that are likely to cause injury.

	All throws (n=14)
Maximum score	11
Minimum score	5
Average score	8

Physical task characteristics

- Chain length, gauge and weight varied, with some being full chain and others a combination or wire rope and chain.
- Where chains were attached to the chassis, technique was limited to the 'throw' technique, with insufficient drop for 'flick' or 'skipping' techniques. The higher anchor point on bolsters allowed drivers to use skipping technique, although not all did so.

- Drivers also have to reach to the anchor point to ensure the chain is sitting in a position that does not result in a sudden release when tensioning. This was not always done, and could be an element to include in training material.
- Chain weights (as held and thrown by drivers) were sampled; the section held ranged from 2.6kg up to 8.8 kg. Sample whole chains weighed up to 9.35, but in most cases the whole chain would not need to be handled.
- Drivers conducted the throwing task from between approximately 1.5m and 5.5m from the truck, depending on the technique used, preference and amount of room available to them.

RPE (Rating of Perceived Exertion) Scores

The average RPE scores for chain throwing among the case study drivers was 5 (Hard), with a range of 2 (“fairly light”) to 9 (between “very hard” and “very very hard/maximal”). These reported exertions indicated that drivers often put a relatively high amount of effort into twitching, which may increase the risk of a sudden or repetitive injury.

Detailed Study Results - Chain tensioning

Survey

- 15 drivers reported injuries associated with chain tensioning; all but one were using twitches.
- Half the injuries were strain/sprain or muscular type injuries, the rest being bruises or lacerations from being struck by or striking against the securing equipment.
- Lost time from injuries reported by drivers included one with 2 days lost time and another with six weeks off work.
- Drivers rated using twitches as 2 out of 5 on the scale (ranging from 1 to 4), and winches as slightly easier at 1.5 (range 1 to 4).
- Managers scored twitch difficulty as 2.5 and winches 2.2.
- There were 12 injuries forwarded from managers associated with securing the load, nine of which specified the use of twitches; they did not result in any lost time.

Case studies

Postural analysis tool - REBA

- From the selected snapshot postures, taken at the beginning, during or end of load tensioning activities, the average REBA score was 8.7, indicating a high level of risk requiring some sort of intervention. As for chain throwing, the task will also include less harmful postures and other contributory factors are not accounted for. However it does provide an indication that tensioning tasks result in postures that are likely to cause injury.

	All (n= 19)	Winch/ratchet (n=4)	Twitch (n=15)
Maximum score	13	7	13
Minimum score	5	5	5
Average score	8.7	5.8	9.5

Physical task characteristics

- The height for tensioners (the hinge of the twitches or winches) ranged from 1400 to 2100mm; using a bar of approximately 800mm alters the operating height depending on where they start the tensioning action. Some drivers indicated that sufficient tension is applied when started the tensioning action with the bar ‘at 3 o clock’ ie at hinge height, and that this reduces the force requirement.
- Ideally drivers should be able to conduct the task between elbow and shoulder heights to place the elbow in mid range and to decrease shoulder and arm elevation.
- Estimates of shoulder height for New Zealand males (including 40mm for footwear) of 45-60 years ranges between 1380 (5^{th} percentile) to 1565mm (95^{th} percentile male). Estimates for elbow height for New Zealand males (including 40mm for footwear) of 45-60 years ranges between 1065(5^{th} percentile) to 1205mm (95^{th} percentile male).
- Manager feedback indicated a higher placement is needed to keep mechanism away from the driver’s face in case it does flick undone, and that this allows them to pull down more readily. However, this would compound the risk resulting from forceful actions with arms above shoulders.
- Also impacting risk of ‘a struck by’ or jarring injury is the design of the anchor point and placement of the chain relative to it; sudden movements if the chain shifts on the anchor point was described by drivers and in injury narratives, and also observed during case studies.

Discussion of results within the context of the log truck driver workforce

A survey of 225 log truck drivers (16% of the workforce) in 2007 (Mackie 2008), found that the average age of the driver workforce was 43 years (Figure 6). At the time it was considered that the workforce was aging so the average age may be higher by now. Given that the average age of the surveyed drivers within this study was 49 and the average age of the case study drivers was 52, it is likely that this study has focussed on a slightly older cross-section of the log truck driver workforce. Given that at least one-third of drivers are likely to be 50 years or older (with an ever-aging workforce), and given the relatively high effort needed to throw chains and secure loads, it is suggested that chain throwing and load securing is likely to be a concern for a significant proportion of the log-truck driver population and for the industry as a whole.

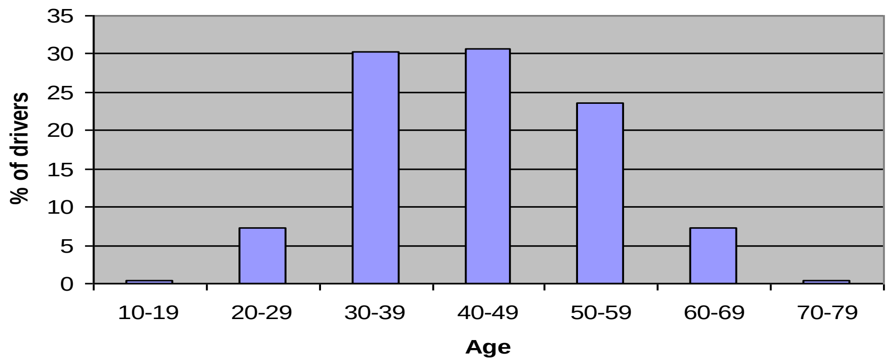

Figure 6. Age of log truck drivers (from Mackie 2008)

Load securing and risk of injury

Problem and aims

Within current log-transport operations in New Zealand, throwing chains and tensioning them via twitches or winches is an activity that all log truck drivers must carry out following loading. However, the log transport industry has identified that truck drivers seem to be sustaining injuries as a result of load securing activities. Chain throwing has been implicated with long-term shoulder pain and load tensioning using twitches is related to periodic incidence of blunt trauma injuries. Both types of injury have shown to be debilitating for some drivers. An injured shoulder through long-term repetitive strain may prevent them from working as might the loss of sight from an eye following a strike from a twitch. The personal, company and societal costs of these injuries within the industry are potentially severe. An aging driver workforce may contribute to the risk of these injuries. Over time the load securing task that is required of drivers may be relatively more demanding as the physical capability of drivers reduces through age.

Log truck load securing requirements

The Log Transport Safety Council has industry standards which represent best practice for the transport of logs in New Zealand. The standards includes a section on load securing which gives guidance on (among other things) arranging the logs, use of restraints and associated devices, the responsibilities of various parties, stanchions and bolsters and load anchor points. Chains must be used to restrain loads and must have a restraining capacity of 2.3-3 tonne depending on where they are used on the rig. The number of chains that must be used depends on a number of factors, but rarely exceeds nine in total.

Chain throwing and chain tensioning

Every time a log truck and trailer is loaded with logs, the load must be restrained by chains, as per the load securing requirements described earlier. In order to position the chains over the packet of logs the driver must project the chains over the logs so that the loose end may be retrieved from the opposite side of the load. There are a number of techniques that are used to achieve this, but the most used (“standard”) technique involves bunching a sufficient length of chain in one hand and then throwing it over the load using and over-arm technique (Figure 7). Given the load securing requirements described earlier, the mass of the chains in the driver’s hand prior to throwing them over the load using the typical throwing technique is approximately 2-4 kg, possibly up to 5 kg, depending on how worn the chains are, the length of chain to be thrown and any mud or dirt that may be attached to the chains if conditions are wet.

Alternative techniques for projecting the chains over the load include:-

- A ‘skipping rope’ technique (Figure 9 and 10) whereby the driver stands some distance back from the side of the rig holding the loose end while turning the chain so that it rotates like a skipping rope. At the right time, the driver lets go and the chain projects over the logs

- A recoil technique where the driver positions himself in a similar position to the skipping rope technique, but then instead jerks the chain rapidly away from the rig and then lets it go at the right time. The recoil force on the chain projects it over the load.

Chain tensioning is achieved using either twitches or winches (Figure 11-14). In both cases a bar is attached to the mechanism so that the driver can apply sufficient torque to apply the required chain tension.

Figure 7. Beginning of standard chain throwing technique

Figure 8. End of chain throwing action

Figure 9. Skipping technique

Figure 10. Skipping technique

Figure 11. Chain tensioning using twitch

Figure 12. Chain tensioning, applying force

Figure 13. Chain tensioning using winch

Figure 14. Winch mechanism

Brief literature review

Injury literature associated with transport and trucks

Published literature pertinent to this study – in particular studies examining injuries associated with tasks secondary to driving, among heavy truck industry – is limited. Most of the industrial/truck related literature refers to either crashes or musculoskeletal disorders (MSD) from driving (eg vibration, manual handling generally) as opposed to loading or throwing or securing loads. A review of ACC data in the Transport and Storage sector (which includes Log Transport as a subsector) over a ten year period identified 83% of the injuries as being related to twitching/ratchetting. The most common injury site was shoulder and lower back/spine – accounting for 40% and 29% respectively of twitching injuries in the workplace. The most common diagnoses were soft tissue injuries which account for 80% of the injuries. An evaluation of the health and safety of log truck drivers in New Zealand (Mackie, 2008) found that 22% of surveyed drivers reported back or neck disorders; 2% indicated difficulty securing and tightening chains. Throwing and securing chains was reported as difficult among some drivers interviewed in the study

Further afield, Speilholz et al (2008) describes how the trucking industry experiences one of the highest work-related injury rates in the United States, but little work has examined hazards and injury prevention methods. Friswell et al (2010) examined work characteristics for light/short haul transport; they required drivers to list their top three safety problems: unloading and delivery dangers feature in their responses. A truck driver survey of nearly 400 drivers in 2006 in Washington reported that back, shoulder, & arm/hand over exertions and slips, trips, & falls were the biggest causes of injuries and lifting heavy objects were noted as the number one cause of injury. Drivers who spent more than 25 percent of their time working with cargo or unloading and loading the truck were twice as likely to report pain. The survey also pointed out that many truckers feel pressured to work long hours at a fast pace, and job satisfaction impacted on their reported injuries.

Shoulder injury mechanisms

Most papers associated with shoulder injuries and throwing are sports related. A number describe muscle recruitment patterns and related biomechanics (eg Escamilla and Andrews, 2009) and these papers do provide some detail and insight into injury mechanisms, especially of the shoulder (and also elbow) region although it is difficult to establish how well this information might correlate with chain throwing. Edouard et al (2010) determined the frequency, location, types and severity of the throwing arm injuries in athletics throwers, collecting throwing injury data using a questionnaire. 75% of throwers had presented one or more injuries of the throwing arm during their career, 40% of them required a time-loss over 28 days. The shoulder was the most commonly injured body part (70%).

A study by Dun et al (2008) looking into different pitching techniques found that the amount of pitching was a stronger risk factor than type of pitches thrown. This implies exposure to throwing could be more relevant than technique, so reducing risk would require reducing the range of hazards associated with task (eg force, rotational stress) or reducing duration/repetition.

However, other studies (Illyez 2005; Aguinaldo et al 2007) established differences in technique and muscle activity between recreational and athletic throwers, implying technique could influence shoulder stability and injury risk.

Gainor et al (1980) studied case histories of acute injuries in throwing, concluding that severe overloading conditions predispose the upper extremity to injury in the throwing mechanism. Rojas et al (2009) also describe pitching (throwing) as an action that produces high forces and torques at the shoulder and elbow, making the area susceptible to overuse injury. Fleisig et al (1996) considered biomechanics of overhand throwing with implications for sports injuries stating that proper throwing mechanics may enable an athlete to achieve maximum performance with minimum chance of injury.

Park et al (2002) examined the shoulder biomechanics and injuries in baseball pitching. They described an extreme range of shoulder movement, high angular velocities and torques, and repetition making the shoulder vulnerable to injury during the baseball pitch. Wieszczyk et al 2009 looked at risk of shoulder and back injury of turning a hand wheel, depending on the effect of height on maximum torque production; workers exerted greatest torque when the valve was located overhead. Cowderoy et al, 2009, describe overuse syndromes in the shoulders of athletes with repetitive overuse or injury of muscles around the shoulder. They describe how the throwing action may lead to a cascade of injuries caused by the repetitive, high-energy nature of the action rather than a specific injury. Repetition is also referred to by Neal and Fields (2010) in their description of peripheral nerve injuries, stating recovery is faster if the repetitive activities that exacerbate the injury can be decreased or ceased.

There is literature relevant to shoulder and musculoskeletal disorders (MSD) in industry. Keyserling (2000) describes a review by The National Institute for Occupational Safety and Health outlining evidence of a causal relationship between workplace exposures to forceful exertions, repetition, awkward posture, and vibration and disorders of the neck, shoulder, and upper extremities.

An ACC review (Boocock et al, 2005) describes insufficient evidence for specific individual risk factors for upper limb disorders, but some evidence combinations of physical risk factors, and age, are associated with neck/shoulder conditions and for hand/wrist arm conditions. Mukhopadhyay et al (2009) state that postures typical in industry - deviated upper arm postures - have a strong association with injury. Overhead work was the focus for Grieve and Dickerson (2008) describing how a combination of organizational, biomechanical and physiological factors contribute to fatigue and injury.

The impact of an aging workforce is discussed in the literature especially with respect to work related musculoskeletal disorders (King et al, 2009). Older workers may be more vulnerable to lost work time and may experience more severe pain symptoms.

A review by Vieira and Kumar (2004) for analysing workplace posture describes studies that identify shoulder pain associated with work involving hands at or above shoulder level, highly abducted (ie out to the side) arms, and forceful postures and repetitiveness. They also describe a review by Buckle and Devereux showing strong evidence that the combination of posture, repetition, force, and vibration is a risk factor for work-related upper limb musculoskeletal disorders.

Methods for evaluating risk of injury

Methods described in the literature to identify risk in the workplace were reviewed to establish an appropriate methodology for the study. Chaffin (2009) argues that occupational biomechanics research continues to provide the intellectual machine that is driving the development of important ergonomics guidelines. Koski and McGill (1994) looked at the likelihood of increased risk of musculoskeletal injury when joint torque strength demands approach the maximum isometric torque, by determining the flexion torque strength capabilities of the shoulder in young men and women. Marshall and Armstrong (2004) considered how to evaluate force using observation; they concluded that the individuals who actually perform the activity provide feedback when evaluating force.

Subjective methods are well documented in conjunction with studies in msd as well as other injuries. Questionnaires and interviews are often an integral study component (eg Fung et al, 2008)

Fordyce et al (2010) in investigating neck injuries in electrical workers pointed out that Industry-wide surveillance allows easier identification of injury patterns and risk factors of various injury types and facilitates the development of targeted prevention and intervention strategies to reduce the occurrence of these injuries.

Gentzler and Stader (2010) risk of MSD among firefighters and emergency medical technicians (EMTs) in tasks associated with repetitive reaching, bending, lifting, and pulling. Ergonomic tools used for the evaluation included the National Institute of Occupational Safety Health (NIOSH) lifting equation, Rapid Entire Body Assessment (REBA), Rapid Upper Limb Assessment (RULA), and anthropometric measurements of equipment and persons; tasks involving reaching or lifting overhead were found to be associated with high risk of injury. Rapid Entire Body Assessment (REBA) REBA was developed by Hignett and Macatamney (2000) to fill a perceived need for a practitioner's field tool, specifically designed to be sensitive to the type of unpredictable working postures.

RULA (rapid upper limb assessment; McAtamney and Corlett, 1993) is a survey method developed for use in ergonomics investigations of workplaces where work-related upper limb disorders are reported. This tool requires no special equipment in providing a quick assessment of the postures of the neck, trunk and upper limbs along with muscle function and the external loads experienced by the body. The RULA action levels provides an indication of level of urgency about the need to change how a person is working as a function of the degree of injury risk.

Jones and Kumar (2010) explored different methods for assessing musculoskeletal risk in sawmills with favourable results for RULA and Job Strain Index. Mehta et al. (2009) explored the effects of physical and mental demands on muscle activity of the upper limb. They indicated that workplace tasks that involve multidimensional demands, such as physical and mental workloads, can increase injury risks, and that it is important to understand the interactive nature of these combined demands. Mehta et al (2010) looked at shoulder fatigue and injury risk demonstrated, through objective and subjective measures, that task performance and biomechanical demands are affected by fatigue, and that this effect varies with individual factors such as gender and age.

Olsen et al 2009 used a combination of video footage, and a hazard tracking checklist and self-report among short-haul truck drivers primarily to look at truck postures – drivers were accurate at self-monitoring frequent environmental conditions, but less accurate at monitoring trunk postures and rare work events. Their studies showed that workers can produce reliable self-assessment data. HSE has produced The Assessment of Repetitive Tasks, a tool designed to help assess repetitive tasks involving the upper limbs. It assesses some of the common risk factors in repetitive work that contribute to the development of upper limb disorders.

Szeto et al (2007) investigated bus driver injuries; although a different type of study to the current one, the methodology is pertinent, with their use of a questionnaire survey as well as physical assessment. The survey included questions on work, musculoskeletal complaints and perceived occupational risk factors associated with each discomfort. Physical assessment consisted of measurement of lumbar spine mobility, hand grip strength, sit-and-reach test, and observation of standing and sitting postures.

Conclusions from background literature

The literature indicates that throwing activities are associated with injuries, and in particular shoulder injuries, and that exposure and technique may both play a part.

Literature about workplace risk factors indicates there are wide ranging contributory factors, including physical (force, repetition, wide ranges of shoulder movement etc) but extending to psychosocial factors such as workpace, stress, along with duration and other issues such as the impact of older workers who may take more time to recover from injury.

Tools for evaluation of injury risk identified include: assessing biomechanics, torque, range of movement and deviated postures; self-report, surveys and interviews for subjective data; and observational techniques such as RULA and REBA are well used and established.

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