Health and Safety Executive

Reducing the risk of kick injury during the shackling and sticking of cattle in abattoirs

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Research Report

Reducing the risk of kick injury during the shackling and sticking of cattle in abattoirs

Tony Wynn
Health and Safety Laboratory
Harpur Hill
Buxton
Derbyshire SK17 9JN

The slaughter operations in abattoirs vary considerably due to different technical design, different stun systems and different killing rates. The shackling and sticking tasks place the operative at a high risk of being kicked during the slaughter task, as the operative is required to work predominantly within the kick envelope, ie within the functional reach of the animal's limbs. It is impossible to stop animals from kicking during slaughter with a stun/kill protocol based on captive bolt stunning. Furthermore, it is difficult to predict which animal will have post stun convulsions and how strong those convulsions will be. This uncertainty makes it difficult to directly control the risk of kicking during the shackling and sticking tasks.

The purpose of this report is to investigate the shackling and sticking tasks, in order to find ways to eliminate or reduce the risk to the operator by redesigning the work task. Beyond this it is a matter of demonstrating that all that is reasonably practicable has been done to protect the welfare of staff performing the stunning, shackling and sticking tasks and making continual incremental improvements in the process, with the aim of reducing the level of risk to the operator.

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- Janet Lim (Assistant Director BMPA)
- John Goodman (Meat and Livestock Commercial Services Ltd)

KEY MESSAGES

- The shackling and sticking tasks place the operative at a high risk of being kicked, as the operative is required to work predominantly within the kick envelope, i.e. within the functional reach of the animal's limbs.

- The main factor that influences the amount of kicking is the efficacy of the stun. The captive bolt gun used, strength and calibre of cartridge, and the positioning of the stun influence stun accuracy.

- Approximately 30% of cattle observed in this study kicked during the shackling task, while approximately 10 % of cattle kicked during the sticking task. The slaughter operations in abattoirs vary considerably due to different technical design, different stun systems and different killing rates. However, the time taken to move the animal from the initiation of the stun to sticking the animal was similar across abattoirs, regardless of design or throughput.

- Alternative stun box designs have the potential to improve operator welfare within the GB slaughter industry, particularly those that allow sticking of the animal, in situ, prior to shackling and hoisting onto the bleed / dressing rail. For example, electrical stunning equipment can eliminate kicking during the shackling and sticking process and should be considered good practice.

- A number of engineering controls (e.g. bollards around the stun box, bleed cradles, chaining the forelegs, etc.) have the potential to reduce the risk of kick injury while shackling and sticking. Industry should explore the feasibility of these controls; conducting further works to examine the efficacy of these solutions in terms of risk reduction.

- A number of administrative controls (e.g. captive bolt gun maintenance, positioning of the operative, training etc.), constituting a safe system of work, have the potential to reduce the risk of kick injury while shackling and, with further research, the use of Personal Protective Equipment (PPE) has the potential to reduce the impact of kick injury.

EXECUTIVE SUMMARY

OBJECTIVES

The aim of this research is to provide information on the ergonomic risk factors associated with the humane slaughter of cattle in abattoirs, in order to establish safe working methods to reduce the risks of operatives being kicked during the shackling and sticking process.

METHODS

This study comprised:

- A literature review to identify what research relating to the slaughter of cattle has been undertaken with reference to operator health and safety;

- A review of incident data on injuries to abattoir workers was conducted, based on details of incidents reported under the Reporting of Injuries, Diseases and Dangerous Occurrences Regulations; and

- Site visits to seven different abattoirs, in order to gain a greater understanding of the nature of the tasks and the equipment used. Organisations were recruited (as far as was possible) to reflect a representative cross-section of the industry and to cover practice at establishments of different sizes.

The study methods used during the site visits incorporated:

- Informal, unstructured interviews with site managers, health and safety representatives and abattoir workers in order to obtain further insight into the task requirements and performance influencing factors. Topics covered included details of their work tasks, equipment, physical environment and the systems of work within which they operate.

- Observation of the slaughter process and, in particular, the shackling and sticking activities in each abattoir for at least one hour during normal working practice. The time between captive bolt stunning and exsanguination (sticking) was recorded for each animal. In addition, each animal was subjectively assessed for the degree of post-stun [clonic] convulsions and activity at both shackling and sticking.

MAIN FINDINGS

1. The slaughter operations in abattoirs vary considerably due to different technical design, different stun systems and different killing rates.

2. The main factor that influences the amount of kicking is the efficacy of the stun. The captive bolt gun (CBG) used, strength and calibre of cartridge, and the positioning of the stun influence stun accuracy.

3. The shackling and sticking tasks place the operative at a high risk of being kicked during the slaughter task, as the operative is required to work predominantly within the kick envelope, i.e. within the functional reach of the animal's limbs.

4. The time taken to move the animal from the initiation of the stun to sticking the animal was similar across abattoirs, regardless of design or throughput.

5. Approximately 30% of cattle observed in this study kicked during the shackling task, while approximately 10 % of cattle kicked during the sticking task.

6. Electrical stunning equipment can eliminate kicking during the shackling and sticking process and should be considered good practice. The use of electrical stunning would have significant cost implications to industry at this time, but may be considered in replacement and new build situations.

7. Alternative stun box designs, that allow the sticking operation to be conducted within the stun box, have the potential to improve operator welfare within the GB slaughter industry, as they could eliminate kicking during the shackling and sticking process.

8. Electrical immobilisation can eliminate post-stun convulsions. However, under the Welfare of Animals at the time of Killing Regulations 2012, electrical immobilisation cannot be carried out within 30 seconds of bleeding, as it may mask signs of inaccurate stun.

9. With further research, potassium chloride (chemical pithing) has the potential to be used as a means of reducing the level of post stun convulsions.

10. A number of engineering controls (e.g. bollards around the stun box, bleed cradles, chaining the forelegs, etc.) have the potential for reducing the risk of kick injury while shackling and sticking.

11. A number of administrative controls (e.g. captive bolt gun maintenance, positioning of the operative, training etc.), constituting a safe system of work, have the potential to reduce the risk of kick injury while shackling and sticking.

12. Personal Protective Equipment (PPE) has the potential to reduce the impact of kick injury when shackling and sticking. Though this control measure requires further research.

POINTS FOR FURTHER CONSIDERATION BY THE INDUSTRY

With respect to the task:

- **Standard operating procedure:** A number of sites visited during the course of this investigation did not have a documented operating procedure for shackling, sticking and allied activities. It is good practice to document and display standard operating procedures (SOP) within the abattoir, as this would contribute to the development of a safe system of work (*this is now a legal requirement under the Welfare of Animals at the time of Killing Regulations 2012*).

- **Access to the killing floor should be restricted:** The number of people present in the shackling and sticking area may contribute to the risk of injury. Restricting the access of anyone other than the operatives performing the stunning, shackling and sticking tasks may reduce the risk of a non-slaughter operative being injured.

- **Improve communication between stakeholders:** Effective communication and sharing of information within the industry may help to reduce the risk of kick injury, as key industry stakeholders share information on good practice or successful risk reduction.

- **Potassium Chloride (KCl):** Research is needed to examine the feasibility of using KCl injections to improve operator safety. Further trials involving larger numbers of animals under commercial conditions would be required in order to establish whether a safe, reliable and humane slaughter protocol can be developed. The use of chemical agents that result in tissue residues cannot be used for the slaughter of animals intended for human consumption unless they are approved by the Food Standards Agency.

- **Electrical stunning:** Further research should be conducted to examine the feasibility of applying an electrical stun / kill slaughter protocol within the UK meat processing industry.

With respect to the individual:

- **Selection, training, on-going supervision and assessment of stunning operators:** successful CBG stun depends on the knowledge and skill of the person who performs the stunning. Therefore, employees need to have received suitable training on how the selected stun method is used. This should include where the stun should be applied, the signs of an effective stun and what to do if the animal shows signs of return to sensibility (*this is now a legal requirement under the Welfare of Animals at the time of Killing Regulations 2012*). It is good practice for other employees working on the killing floor to have similar training as the operator performing the stunning and to have ready access to a backup stunning device, should it be required.

- **Operator fatigue:** Operator fatigue is a major cause of missed CBG shots and can lead to inaccurate stunning of animals and the necessity for additional stunning attempts. The prevention of overloading / fatigue may require employment of two CBG operators or frequent rotation of cross-trained operators. Assessment of stunning efficiency at the end of the shift would help to identify if fatigue is a significant issue.

With respect to the environment / equipment:

- **Alternative stun box design:** Industry should look at alternative stun box designs, particularly those that allow sticking of the animal, in situ, prior to shackling and hoisting onto the bleed / dressing rail. From a worker safety point of view, sticking should be performed whilst the animal is still in the tonic phase. This makes the cut easier to carry out and helps protect the slaughter personnel from kick or knife injury. Therefore, alternative stun box designs have the greatest potential for improving operator welfare within the UK slaughter industry.

- **Alternative killing floor design:** A number of possible design solutions are presented that modify the shackling task in an attempt to reduce the risk to the operator by limiting the amount of work that the operator undertakes within the kick envelope. Industry should explore the feasibility of these suggestions; conducting further work to examine the efficacy of these solutions in terms of risk reduction.

- **Operational maintenance of stunning equipment:** One of the most common causes of low efficacy scores for use of captive-bolt stunning equipment is the use of unclean or poorly serviced guns, with worn out parts, due to poor maintenance. As such, each abattoir should have a system of verified maintenance in which the CBG must be cleaned and serviced, following the manufacturer's recommendations, to maintain maximum hitting power and to prevent misfiring or partial firing (*this is now a legal requirement under the Welfare of Animals at the time of Killing Regulations 2012*).

- **Personal protective equipment (PPE):** A number of existing items of PPE and sports equipment that could be adapted for use in the abattoir environment were identified. However, very few of these items have been trialled or tested in occupational conditions and as such there may be limitations to using these items as PPE. It is recommended that additional research is conducted to establish the suitability and efficacy of these types of equipment as PPE in the abattoir setting.

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1. INTRODUCTION

Traditionally, pithing was used within the UK slaughter industry to protect the operator by reducing the risk of workers being injured by the uncoordinated movements of stunned animals, particularly when the animal was dressed on the floor (1). Pithing involves inserting a cane, usually a flexible wire or polypropylene rod, through a hole in the head made by a captive bolt stunner. This kills the animal by lacerating the central nervous tissue, physically destroying the brain stem and surrounding parts of the central nervous system (2). However, since the BSE (Bovine Spongiform Encephalopathy) outbreak, it is no longer permissible for animals slaughtered for human or animal consumption to be pithed following stunning.

BSE is a fatal, degenerative disease of the central nervous system that occurs in cattle. It is one of a number of similar diseases known as transmissible spongiform encephalopathies (TSE), which occur in humans and various animals (3). When slaughtering cattle for food for human consumption, there is a risk of exposure to the BSE agent, which may be present in brain and spinal cord (c.f. Specified Risk Materials; SRM). The removal of SRM in cattle destined for the food chain reduces the risk of BSE contamination. Therefore, the method of slaughter to be used should generate the least risk of contamination of individuals, or the environment, with potentially infected SRM (4). As part of measures to prevent the possible spread of BSE, following the discovery of traces of brain material in the circulation of pithed cattle, the Restriction on Pithing (England) Regulations 2001[1] (5), state that: "No person shall pith any bovine, ovine or caprine animal prior to slaughtering it for human or animal consumption."

Since this date, the typical approach is to stun the animal with a captive bolt stunner in order to "render the animal immediately insensible to pain and to ensure that it remains unconscious until it is dead" (6). Once the animal is removed from the stunning box, an operative attaches a shackle to the rear leg or legs of the beast and raises it via the use of a hoist. Once hoisted an operative then 'sticks' the animal, which involves bleeding the animal by incising the carotid arteries or the vessels from which they arise, allowing enough time for the animal to die from exsanguination before it regains consciousness. This process prevents or reduces the release of brain tissue and lessens the risk of contamination of personnel and the work environment with potentially infected SRM. However, this method leaves the brain stem intact, with the possibility that some animals may recover their breathing reflex before exsanguination has taken place (2).

Evidence suggests that cattle stunned in this way exhibit an increased level of involuntary kicking movements compared with pithing (7-9). Excessive, sudden convulsions by the animal during the shackling and sticking process may present a hazard to the operator. For example, a survey conducted by Bristol University for the Department for Environment, Food and Rural Affairs (DEFRA; 10) illustrates that the ban on pithing has had a negative effect on operator safety. 84% of abattoir operators surveyed during the study believed that there was an immediate negative effect on operative health and safety when the ban on pithing was enforced, while 63% believed that there had been an increase in the number of accidents at sticking and shackling since the ban on pithing was enforced. Similarly, 47% believed that the severity of accidents had increased since the introduction of the ban on pithing, while, 74% of respondents had experienced difficulties during shackling and sticking since the ban on pithing was enforced due to the increased movement / kicking of cattle. In addition, there have been several serious injuries reported both in the UK and Europe.

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[1] Due to devolved Government separate implementing Regulations, with similar provisions, have been made in Scotland, Wales and Northern Ireland, i.e. the Pithing (Scotland) Regulations 2001 are applicable in Scotland, etc.

1.1 AIM

To provide information on the ergonomic risk factors associated with the humane slaughter of cattle in abattoirs, in order to establish safe working methods to reduce the risks of operatives being kicked during the shackling and sticking process.

1.2 OBJECTIVES

In order to achieve the aim of this project the following objectives were identified:

1. Undertake a literature review of current practice in the UK and abroad with regard to both the influence of human factors (HF) and the use of personal protective equipment (PPE).

2. Undertake a number of site visits to abattoirs to view current practice. These would be selected from a cross-section of the industry in order to be representative of the range of working methods currently employed.

3. Identify from the site visits 'good practice' to reduce the risk of being kicked when attaching the shackle or sticking the animal.

2. METHODOLOGY

2.1 INCIDENT ANALYSIS

A review of incident data on injuries to abattoir workers was conducted, based on details of incidents reported under the Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 1995 (RIDDOR; 11), to provide objective evidence of the nature and extent of the problems associated with the shackling and sticking of cattle; helping to identify the key risks and how these might be controlled. The RIDDOR Regulations in place at the time of the research required that employers report any injuries to employees resulting in an absence from normal work for more than three days to the Health and Safety Executive (HSE). Under the RIDDOR system, HSE categorises injuries in terms of severity (fatal, major, or over-3-day absence[2]), nature and bodily site of injuries, age, sex, and employment status of injured persons, and industry of occurrence. At a national level, recorded accident data, such as that collected under RIDDOR, is used by health and safety enforcement agencies to inform intervention strategies. Accurate reporting of work-related injuries and illnesses can help to identify unsafe work environments and work practices; eliminate hazards; or, at least, control the health and safety risks to employees.

2.2 LITERATURE REVIEW

A literature review was conducted in order to identify what research relating to the slaughter of cattle has been undertaken with reference to operator health and safety. A search was conducted using the key words: Abattoirs, abattoir design, humane slaughter, captive bolt stunning, shackling, sticking, electrical stunning, non-penetrative concussive stunner, halal slaughter, kosher slaughter, abattoir injury, cattle handling, beef processing, and pithing. The databases searched included: Oshrom, Oshupdate, Web of Knowledge, Ergonomics Abstracts, Healsafe, CAB Abstracts, Agricola, Foodline and Food Science and Technology Abstracts. 194 papers that made specific reference to the slaughter of cattle were identified. From this, duplicates, non-English language papers, and papers that covered topics outside the scope of this report (e.g. cattle handling in lairages and marts, veterinary practices, animal physiology, and zoonoses) were excluded from the review process leaving a total of 104 papers that were relevant to the current project. Web searches using the Google scholar search engine and similar key words were performed periodically to ensure that relevant current reports were not missed.

2.3 SITE VISITS

HSL Ergonomists completed site visits to seven different abattoirs, recruited via the British Meat Processors Association (BMPA). During each of the site visits a company Health and Safety official accompanied the HSL researchers and informed workers about the project and why they were being observed. The purpose of these visits was to gain a greater understanding of the nature of the tasks and the equipment used, as it was hypothesised that there would be a wide variety of spatial layouts and a range of working practices within the slaughter industry. Therefore, organisations were recruited (as far as was possible) to reflect a repesentative cross-section of the industry and to cover practice at establishments of different sizes.

- Small abattoirs were defined as having a throughput of less than 100 animals per week;
- Large abattoirs were defined as having a throughput of more than 750 animals per week; and

[2] The requirement to report over three day injuries became over seven days as of April 2012.

- Abattoirs with throughputs between these ranges were defined as medium sized abattoirs.

The study methods used during the site visits incorporated:

- Informal, unstructured interviews: Where possible these were conducted with site managers, health and safety representatives and abattoir workers in order to obtain further insight into the task requirements and performance influencing factors. Topics covered included details of their work tasks, equipment, physical environment and the systems of work within which they operate. This also included the opinions of the workers with regard to risk and physical effort involved. Collectively, this was used to highlight both the potential risks and the viability / practicality of any suggested risk reduction measures.

- Observation of slaughter process and, in particular, the shackling and sticking activities in each abattoir for at least one hour during normal working practice. The time between captive bolt stunning and exsanguination (sticking) was recorded for each animal. This provides information about the amount of time the operators are exposed to the kicking risk and informs decisions regarding best practice, as any working procedures must be achieved within the context of the Welfare of Animals at the time of Killing (England) Regulations 2012 (12). In addition, each animal was subjectively assessed for the degree of post-stun [clonic] convulsions and activity at both shackling and sticking, using the scoring system described in Table 1.

Table 1 Assessment of the degree of kicking at shackling and sticking **(10)**

Score	***Descriptor***	***Description***
0	No activity	Very little movement that causes no interruption of the procedure and no risk to operator safety.
1	Mild activity	Some physical movement of limbs that is manageable such that there is no significant delay to the procedure and no significant risk to operator safety.
2	Moderate activity	Considerable physical movement of the limbs that produces a delay to the operation and a potential danger to operator safety.
3	Severe	Gross physical movement that incurs a significant delay in the operation with a concurrent danger to the operative.

3. INCIDENT ANALYSIS

This report covers a ten-year period from 1st April 2000 to 31st March 2011. It is based on details of incidents reported under the Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 1995 (11). All 2011 figures were based on provisional RIDDOR data that would not be finalised until after 1st April 2012 to allow for validation of data and late reporting.

3.1 UNDER REPORTING

While the HSE are informed about almost all relevant fatal workplace injuries, it is known that non-fatal injuries, particularly those injuries involving over-3-day absence from work, are substantially under-reported (13-18). Currently, it is estimated that just over half of all such injuries to employees are actually reported, with the self-employed reporting a much smaller proportion (13). When levels of non-fatal injuries (major as well as over-3-day) officially reported to the HSE are compared with self-assessed reports through the Labour Force Survey[3] (LFS), under-reporting is estimated to be 42.9% for employees and 63.4% for the self-employed (19). Similarly, Davies, Kemp and Frostick (14) investigated the under-reporting of accidents to the HSE under RIDDOR among patients attending the Royal Liverpool University Hospital for treatment of work-related injuries and found that only 30% of accidents were reported.

3.2 POPULATION

Where injury rates are used they have been calculated based on the following assumptions:

The Food Standards Agency (FSA) does not collect data on the number of licensees currently operating in the UK. However, they have issued approximately 11,000 slaughter licences since they were introduced in 2000 (20). This figure does not account for the type of animal that is being slaughtered, neither does it identify workers that have left the industry, or that are licensed but do not perform shackling / sticking as part of their normal work routine. A figure of 5,000 is a more conservative estimate of the number of slaughtermen and women working in the UK. There are currently 865 establishments, licensed by the FSA, to process domestic ungulates i.e. cattle, calves, sheep, goats, pigs, bison and water buffalo (21). A figure of 5,000 would equate to an average of 5.78 licensed slaughtermen per abattoir. Where comparisons are made to the wider meat processing industry a figure of 80,000 workers is used (22).

3.3 FATAL INJURIES

There were no fatal kick related injuries during the 10-year reporting period.

3.4 MAJOR INJURIES

- There were 19 major kick related injuries during the 10-year reporting period (Figure 1).
- The major injury rate per 100,000 workers decreased significantly from 40 in 2009/10 to 20 in 2010/11, a decrease of 50% (Table 2).

[3] The LFS is a self-report measure drawn from a stratified random sample of UK households providing data on labour market statistics and related topics such as training, qualifications, income and disability.

- By comparison there were 268 major incidents involving an animal or handheld tools / equipment reported by the meat processing industry as a whole during the same reporting period.
- This equates to an average injury rate per 100,000 workers of 321. 6 over the 10-year period. The 3-year rolling average injury rate per 100,000 workers between 2008/11 was 21.6, down from 38.4 between 2001/04.
- There were 27,096 major injuries at a rate of 91 per 100,000 workers reported in total by the GB workforce in 2009/10 (23).

Table 2 Summary of 'kick related' injury rates (per 100,000 workers) April 2001 – March 2011provisional (p)

	01/02	*02/03*	*03/04*	*04/05*	*05/06*	*06/07*	*07/08*	*08/09*	*09/10*	*10/11*
Major	40	60	20	20	60	0	60	60	40	20
Over-3-day	80	160	60	20	60	80	80	180	60	180
Total	120	220	80	40	120	80	140	240	100	200

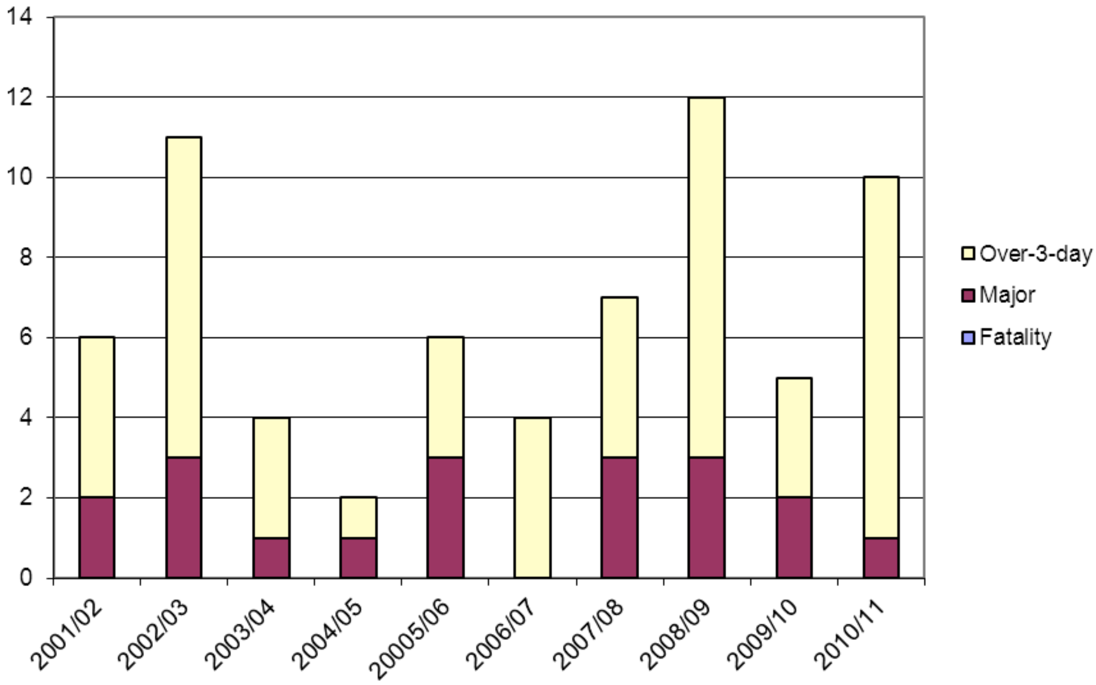


Figure 1 Summary of 'kick related' injuries April 2001 – March 2011(p)

3.5 OVER-3-DAY INJURIES

- There were 48 over-3-day kick related injuries during the 10-year reporting period.
- The over-3-day injury rate per 100,000 workers increased significantly from 60 to 180 in 2010/11 (i.e. an increase of 200%)
- The combined number of major and over-3-day injuries rose from 5 to 10 in 2010/11
- The combined major and over-3-day injury rate rose from 100 to 200 per 100,000 workers in 2010/11

- By comparison there were 1582 minor (over 3-day) injuries involving an animal or handheld tools / equipment reported by the meat processing industry during the same reporting period.
- This equates to an average injury rate per 100,000 workers of 189.84 over the 10-year period.
- The 3-year rolling average injury rate per 100,000 workers between 2008/11 was 146.4, down from 240 between 2001/04.
- There were 96,271 over-3-day injuries at a rate of 323.5 per 100,000 workers reported in total by the GB workforce in 2009/10 (23).

3.6 RATIO OF MAJOR TO OVER-3-DAY

Table 3 and Figure 2 show the ratio of over-3-day injuries to major for the years 2001/02 to 2010/11.

Table 3 Ratio of over-3-day to major injuries

	01/02	*02/03*	*03/04*	*04/05*	*05/06*	*06/07*	*07/08*	*08/09*	*09/10*	*10/11*
Major	2	3	1	1	3	0	3	3	2	1
Over-3-day	4	8	3	1	3	4	4	9	3	9
Ratio	2:1	2.66:1	3:1	1:1	1:1	-	1.33:1	3:1	1.5:1	9:1

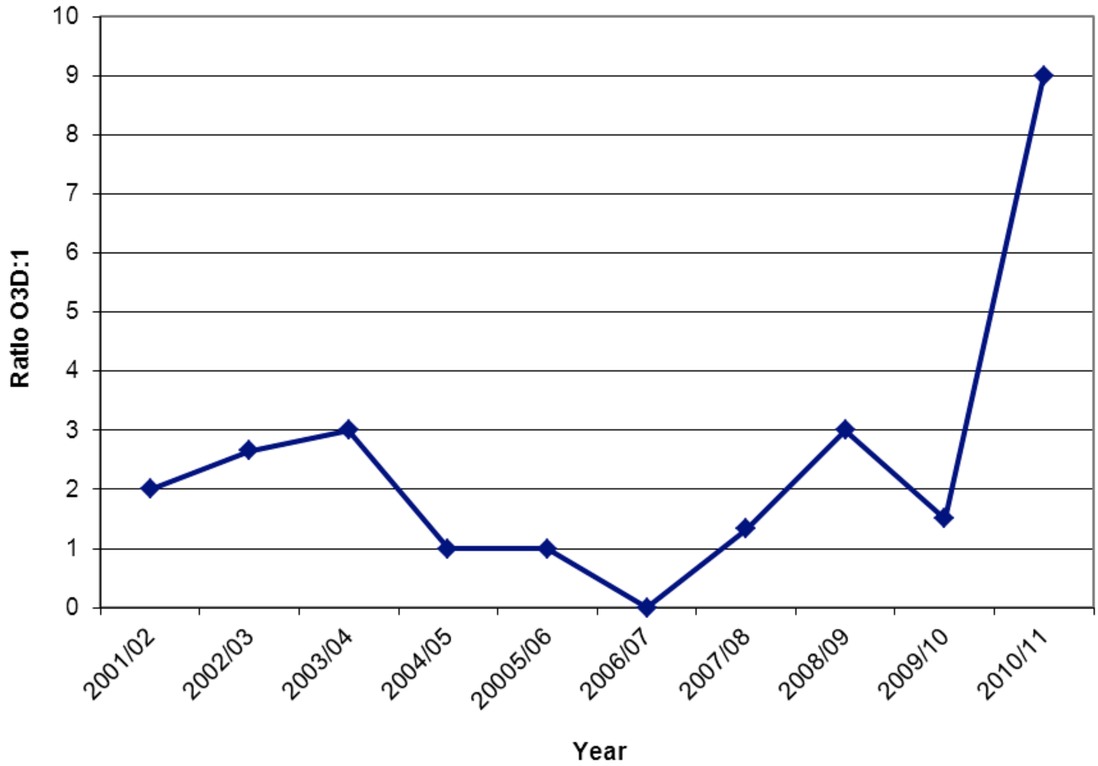


Figure 2 Ratio of over-3-day to major injuries

3.7 THREE-YEAR ROLLING AVERAGES

Three-year rolling averages are calculated to smooth out variability and provide a clearer picture of overall trends (Tables 4 & 5, and Figure 3).

- The 3-year rolling average of the combined number of major and over-3-day injuries has increased over the last five years (from 5.34 to 9).
- The 3-year rolling average "combined major and over-3-day injury rate" has increased from 173.3 to 180 per 100,000 workers over the last 12 months.

Table 4 3-year rolling average of number of injuries April 2001 – March 2011(p)

	01/04	*02/05*	*03/06*	*04/07*	*05/08*	*06/09*	*07/10*	*08/11*
Major	2	1.67	1.67	1.34	2	2	2.67	2
Minor (O3D)	5	4	2.3	2.67	3.67	5.67	5.34	7
Total	7	5.67	4	4	5.67	7.67	5.34	9

Table 5 3-year rolling average of injury rates (per 100,000 workers) April 2001 – March 2011(p)

	01/04	*02/05*	*03/06*	*04/07*	*05/08*	*06/09*	*07/10*	*08/11*
Major	40	33.3	33.3	26.6	40	40	53.3	40
Minor (O3D)	100	80	46.6	53.3	73.3	113.3	120	140
Total	140	113.3	80	80	113.3	153.3	173.3	180

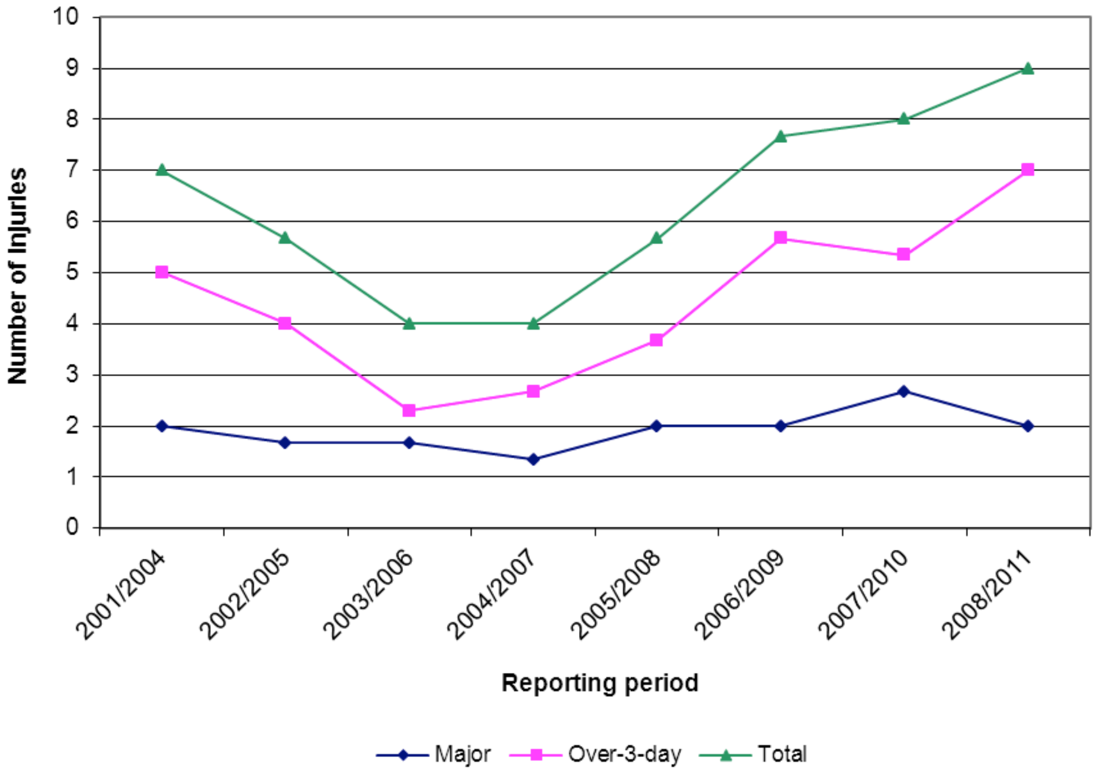


Figure 3 3-year rolling average of number of injuries April 2001 – March 2011(p)

3.8 NATURE OF INJURY

Figures 4 and 5 illustrate the distribution of all injuries. This information shows that:

- Overall the most frequently occurring "nature of the injury" was "Laceration" with 29 accidents, resulting in 44% of all injuries;
  - Fracture accounted for 20% of all injuries with 13 incidents recorded;
  - Contusion injuries accounted for 19% of all injuries, with 13 incidents recorded.
- For major injuries, "Fracture" was the most common nature of injury with 10 incidents (53%);
  - Lacerations accounted for 37% of all major incidents, with 7 incidents reported;
- For over-3-day injuries, "Lacerations" were the most common nature of injury, with 22 incidents (46%) reported;
  - "Contusions" accounted for 27% of all over-3-day injuries (13 incidents)
  - "Superficial injuries" accounted for 15% of all over-3-day injuries with 7 incidents reported.

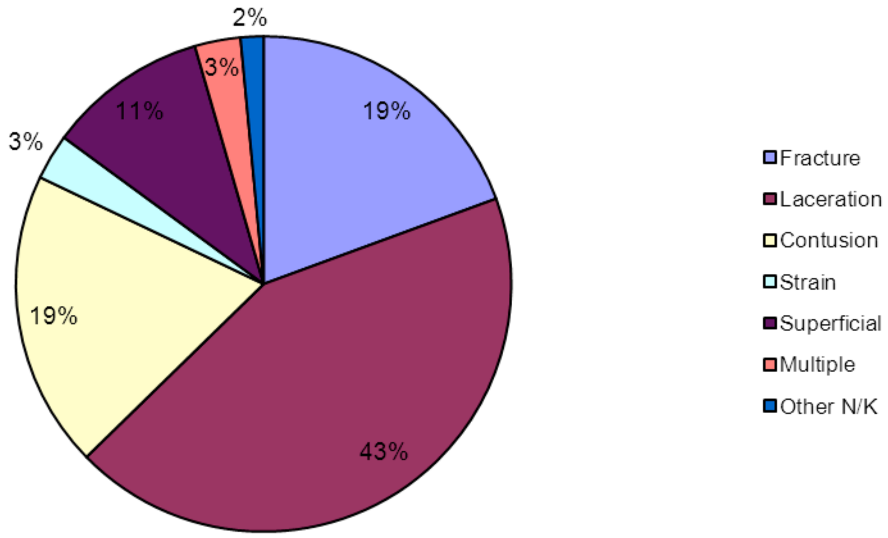


Figure 4 Nature of the injury, all severities of injury (%)

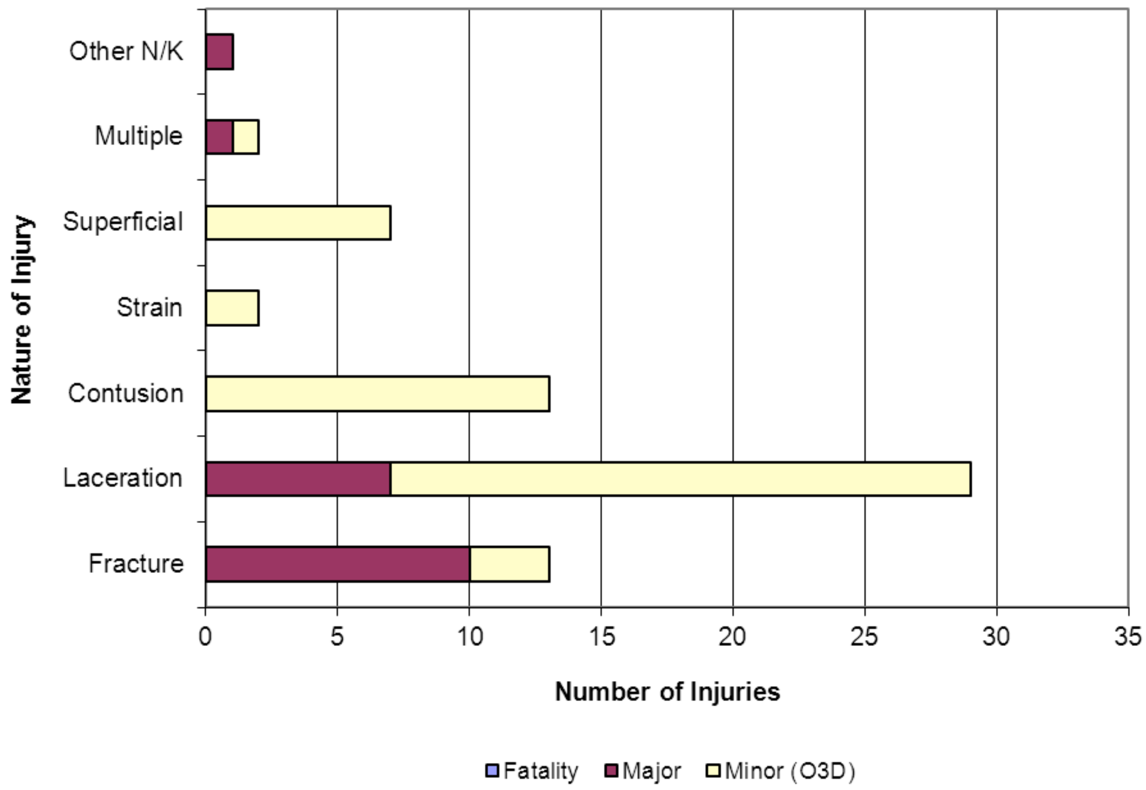


Figure 5 Nature of injury and severity of injury

3.9 PART OF BODY INJURED

Figures 6 and 7 provide information on the site injury. In particular the following is apparent:

- Overall, the upper limb[4] accounted for 46 incidents, resulting in 70% of all injuries;
    - The trunk and back accounted for 7 incidents, resulting in 10% of all injuries;
    - The head, face and eye accounted for around 13% (9 incidents) of all injuries;
    - The lower limbs and foot accounted for 3 incidents (4% of all injuries).
- For major injuries, injuries to the upper limbs accounted for 12 incidents, around 63% of all injuries;
    - There were 2 major injuries to the head, face and eye (11% of all major injuries)
    - There were 2 major injuries to the lower limbs and foot (11% of all major injuries)
- For over-3-day injuries, the upper limbs accounted for 34 (71%) of all over-3-day injuries
    - There were 7 over-3-day injuries to the head, face and eye (around 15% of all over-3-day injuries)
    - There were 5 over-3-day injuries to the torso (around 10% of all over-3-day injuries)

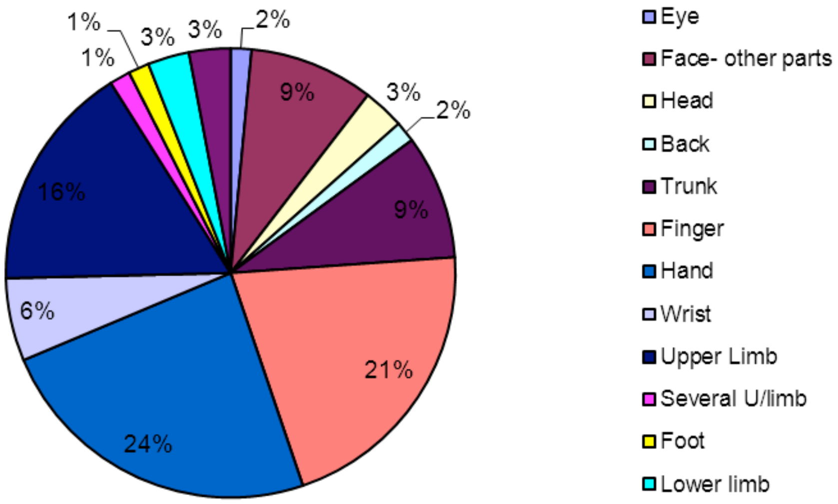


Figure 6 Part of body injured, all severities of injury (%)

[4] Upper limb includes finger/thumb(s), hand, wrist, rest of upper limb and several locations of upper limb.

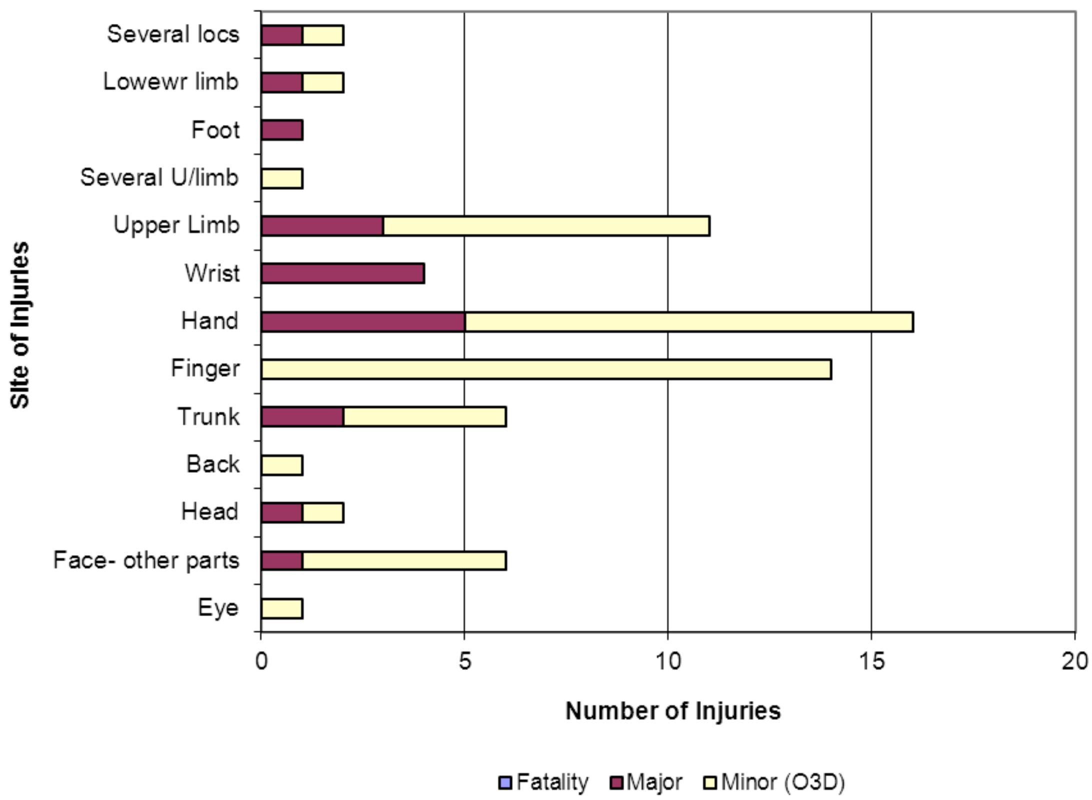


Figure 7 Site of injury and severity of injury

3.10 KIND OF ACCIDENT

Figures 8 and 9 record the breakdown of the kind of accident against severity of injury, showing:

- Overall 36 incidents (55%) were recorded as "injured by animal" (Group 14);
  - Group 05 (Injured while handling, lifting or carrying) accounted for 13 incidents, resulting in 19% of all accidents;
  - Group 02 (hit by a moving, flying or falling object) accounted for 15 incidents, resulting in 22% of all accidents.
- For major injuries 12 (63%) were recorded as "injured by animal";
  - Group 05 accounted for 3 incidents, resulting in 16% of all major accidents;
  - Group 02 accounted for 3 incidents, resulting in 16% of all major accidents.
- For over-3-day injuries "injured by animal" accounted for 24 (50%) of all over-3-day injuries;
  - Group 05 injured while handling, lifting or carrying 10, resulting in 21% of all over-3-day injuries;
  - Group 02 accounted for 12 incidents, resulting in 25% of all over-3-day injuries.

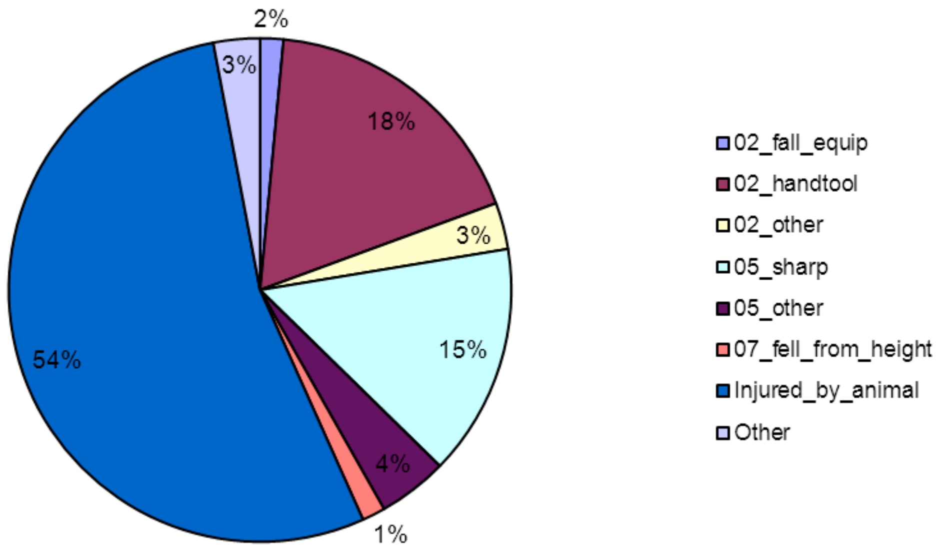


Figure 8 Kind of accident, all severities of injury (%)

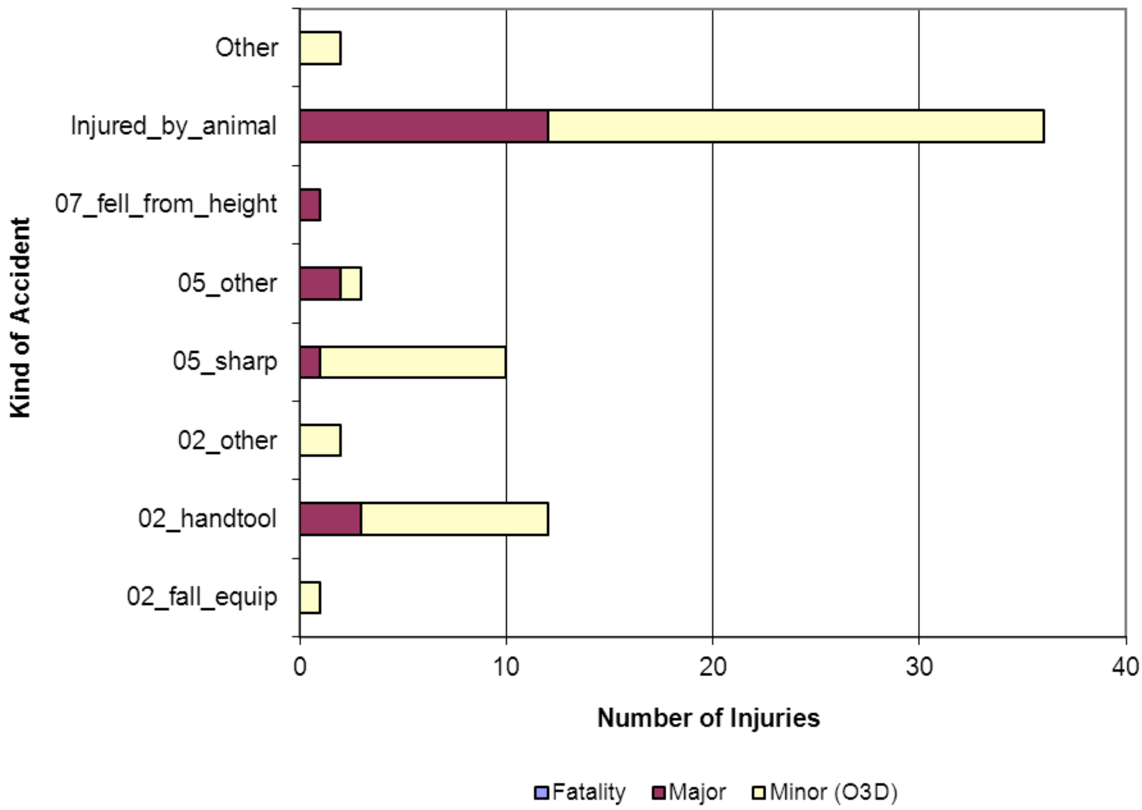


Figure 9 Severity of injury and agent of accident

3.11 AGENT OF ACCIDENT

Figure 10 and 11 give information on the agent of accident against severity of injury. This information shows that:

- Overall, cattle, excluding bulls, accounted for 37% of all injuries (24 incidents)
    - 21 incidents, 31% of all injuries involved cutting, separating including, knives, scissors etc.;
    - 18% of injuries were caused by "Farm animals, including pig, sheep, goat, poultry, deer and ostrich";
- For major injuries, 9 (47%) were recorded under the "cattle, excluding bulls" code
    - 5 incidents (26%) of all major injuries involved cutting and separating using knives, scissors, etc.;
    - 3 incidents (16%) of all major injuries were caused by "Farm animals, including pig, sheep, goat, poultry, deer and ostrich";
- For over-3-day injuries, 15 (31%) were recorded under the "cattle, excluding bulls" code;
    - 1 incident (2%) of all over-3-day injuries involved cutting and separating using knives, scissors, etc.;
    - 9 incidents (19%) of all over-3-day injuries involved "Farm animals, including pig, sheep, goat, poultry, deer and ostrich".

These figures include incidents that are not recorded under the "injured by animal" code, which were included when the information contained in the RIDDOR entry identified the involuntary reflex 'kicking' of an animal at slaughter as the underlying mechanism for the accident e.g. incidents where the abattoir worker was stabbed / stabbed himself or herself with a knife because they were caught by a kicking cow. These incidents were recorded under code 04.06 (Cutting, separating including knives, scissors, shears, hedge cutters, axe, cleaver, hydraulic cutters) and account for around 31% or 21 incidents in total.

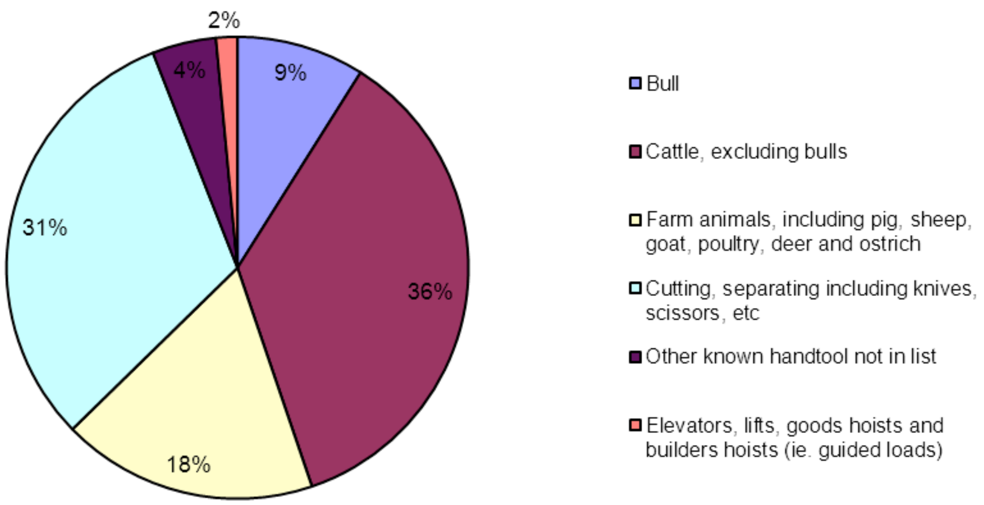


Figure 10 Agent of accident, all severities of injury (%)

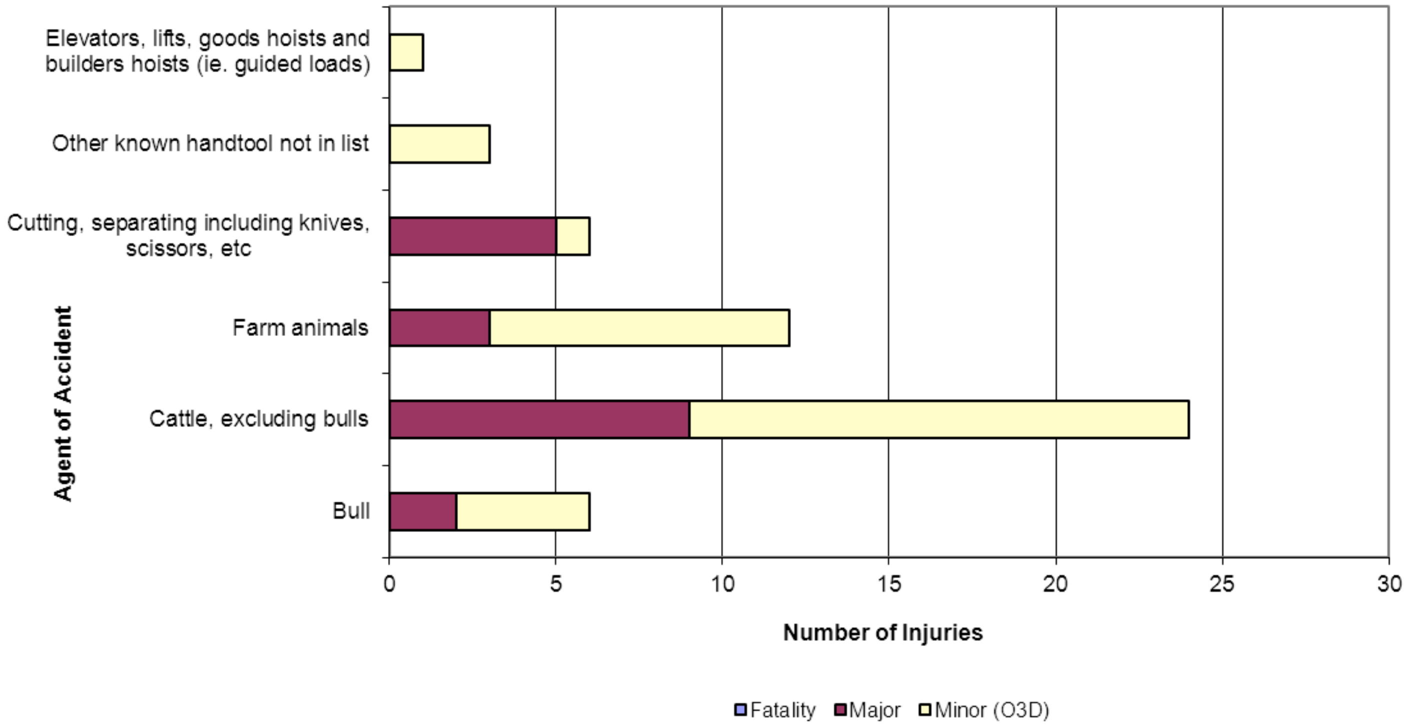


Figure 11 Severity of injury and agent of accident

4. THE SLAUGHTER PROCESS (TASK)

4.1 THE SLAUGHTER PROCESS

The slaughter operations in abattoirs vary considerably due to different technical designs, stun systems, and killing rates (24). Figure 12 shows the slaughter and dressing procedures carried out during line slaughter. The typical process is as follows:

- The stun box is loaded with an individual animal;
- When the animal presents its head in a suitable position it is shot with a contact firing captive bolt gun;
- The stunned animal is ejected from the side of the stunning pen;
- The hind leg is shackled and the animal is hoisted onto the bleed rail, where it is stuck by making a 30-cm longitudinal cut in the jugular crease at the base of the animals' neck between brisket and jaw. A second knife is then inserted into the thoracic cavity and used to sever the jugular and carotid vessels coming from the heart.
- After the animal is sufficiently bled, it is transferred from the bleed rail to the dressing line during the legging phase (25). In the continuous line system the animal is hoisted up for bleeding and the carcass remains in this position during the entire process (26). In this system, changing from the bleeding hooks to the dressing hooks has to be done while the carcass is vertical. To accommodate this process, two rails with different heights are required.
- All subsequent slaughtering and dressing (hide pulling, evisceration, carcass splitting, etc.) are carried out as the animal travels along the dressing line, with each task carried out at a designated workstation.

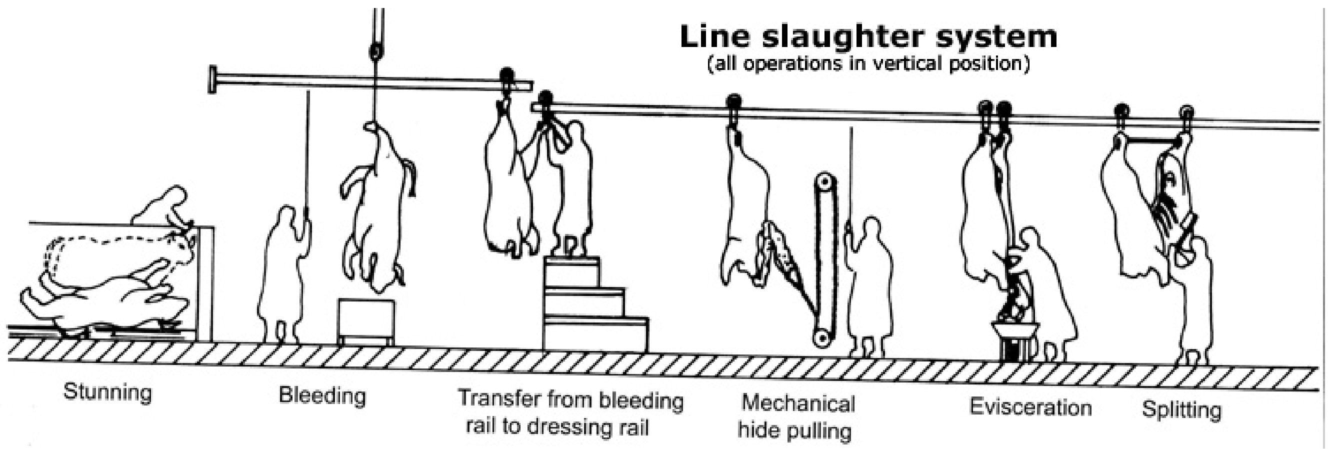


Figure 12 Continuous line slaughtering **(25)**

4.1.1 Humane Slaughter Regulations

For the stunning and killing of farm animals for commercial slaughter or disease control purposes it is necessary to select those procedures whose proper application have the most advantages in terms of animal welfare (27). The European Union Council's regulation on animal welfare, 1099/2009, which was published in the Official Journal of the European Union on 18th of November 2009 and which apply from 1st of January 2013 (28), provides a legal framework for ensuring overarching welfare outcomes are achieved. Regulation 1099/2009 obliges business operators or any person involved in the killing of animals to take the necessary measures to ensure animals are spared any avoidable pain, distress, or suffering when killed and requires measures to be taken to ensure animals:

- Are provided with physical comfort and protection, in particular by being kept clean in adequate thermal conditions and prevented from falling or slipping;
- Are protected from injury;
- Are handled and housed taking into consideration their normal behaviour;
- Do not show signs of avoidable pain or fear or exhibit abnormal behaviour;
- Do not suffer from prolonged withdrawal of feed or water; and
- Are prevented from avoidable interaction with other animals that could harm their welfare.

Article 26(1) of Regulation 1099/2009 allows EU Member States to maintain existing national rules that were already in force on 8 December 2009, where these provide more extensive protection of animals at the time of killing than the minimum standards prescribed by Regulation 1099/2009. The Welfare of Animals at the time of Killing (England) Regulations 2012 (28) are the domestic Regulations that implement 1099/2009 in England (due to devolved government separate implementing Regulations, with similar provisions, will be made in Scotland, Wales and Northern Ireland, i.e. the Welfare of Animals at the time of Killing (Scotland) Regulations 2012 will be applicable in Scotland, etc.

The underlying principles of these Regulations reflect the World Organisation for Animal Health (OIE) Terrestrial Animal Health Code, which includes guidelines for the slaughter of animals and for the killing of animals for disease control purposes. The OIE humane slaughter guidelines are designed to minimise avoidable pain and suffering at every stage of the pre-slaughter and slaughter processes, until the death of the animal (29). The competence of the operators and the appropriateness and effectiveness of the method used for stunning are the responsibility of the slaughterhouse management and should be checked regularly by a competent authority. Only permitted methods may be used to stun or kill animals. Annex I of 1099/2009 (28) lists the permitted methods of stunning and any specific requirements for those methods. Persons carrying out stunning should be properly trained and competent and should ensure that:

- The animal is adequately restrained;
- Animals in restraints are stunned as soon as possible using a method permitted in Annex I of 1099/2009 (28), which lists the acceptable methods of stunning and any specific requirements for those methods.

- The equipment used for stunning is maintained and operated properly in accordance with the manufacturers recommendations, in particular with regard to the species and size of the animal;

- The instrument is applied correctly;

- Stunned animals are bled out (slaughtered) as soon as possible, although, if the stunning method causes irreversible loss of consciousness (as a result of severe brain trauma), exsanguination is needed only to relieve the carcass of blood (30);

- Animals are not stunned when slaughter is likely to be delayed;

- In addition, when an animal is not properly stunned, a back-up procedure must be used immediately.

Similarly, it is recommended that the animal is effectively stunned before sticking commences unless otherwise approved by a controlling authority. Hoisting must not commence until the animal is confirmed insensible and dressing must not commence until the animal is permanently insensible (31).

4.2 RESTRAINT

The Welfare of Animals at the time of Killing (England) Regulations 2012 (12) require that bovine restraining pens are designed and operated to protect the animal from avoidable pain, suffering agitation, injuries or contusions while entering or confined in it and provide effective restraint, so as to permit accurate stunning and allows the head of the animal to be released immediately after the animal has been stunned. This is to ensure stability of the animal so that the stunning and bleeding operations can be carried out accurately and properly (32). The restraint method is very important, because it has a great impact on the overall amount of stress during the whole procedure, e.g. how much pain animals feel depends on how stressed they are, etc. (33;34). A stun box is the most common method of restraining cattle (Figure 13). The stun box must be large enough to take any cattle normally presented for slaughter (35). The size of the box should be just wide enough to prevent the animal from turning around, making it easier to stun accurately. The design of the box should ensure that restraint does not apply excessive pressure, or cause struggling / vocalisation in animals, it should be engineered to reduce noise (e.g. air hissing and clanging metal), it should be devoid of sharp edges in the restraint that would harm the animal and the floor of the box should be non-slip (29). Furthermore, the stun box should not have a solid wall at the head end, as cattle will move into it better if they can see a space beyond it (36).

Within the stun box there are a range of options for additional restraint designed to help meet welfare regulations. The types of restraint available range from active devices, which physically hold the head in place, to passive devices that encourage the animal to hold its head in the correct position (37). The type of restraint used will depend on the design and layout of the individual abattoir. Table 6 provides a summary of the additional restraint systems available and describes the advantages and potential disadvantages of each system.

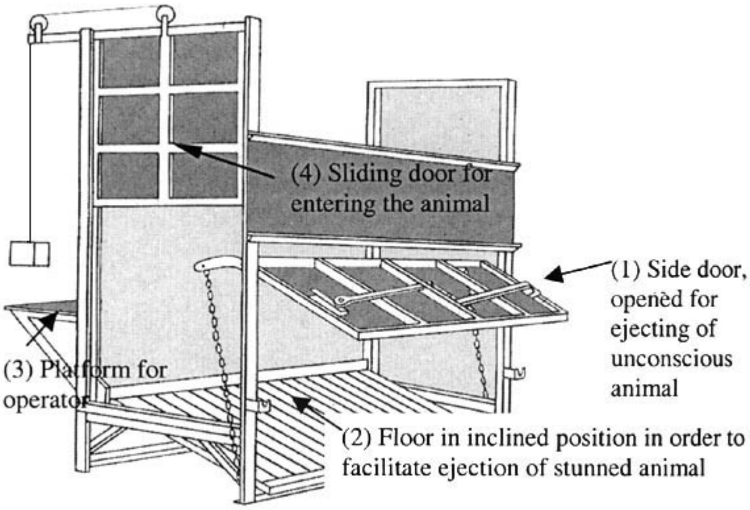


Figure 13 Standard stun box (32)

Table 6 Summary of additional restraint options (37)

	Active		*Part-passive*	*Passive*
	Head yoke and chin lift	*Cantilever neck yoke*	*Hinged neck yoke*	*Head shelf*
Effect of restraint on animal	Held securely in a fixed position	Backwards movement restricted	Backwards movement restricted	Downwards movement restricted
Advantages	Animal held stable; Allows accurate shot; Good for training staff; Can hold heavy animals Animal cannot move back.	Animal held stable; Allows accurate shot; Good for training staff; Animal cannot move back.	Animal held stable; Allows accurate shot; Head held in good position; Animal cannot move back.	No distraction to animal; No power requirements; No extra stress to the animal; Not physically restrained; No effect on throughput time.
Possible disadvantages	Extra stress experienced; Slower throughput time; Increased time in stun box prior to stunning; Disruption of carcass removal.	Extra stress experienced; Slower throughput time; Increased time in stun box prior to stunning; Disruption of carcass removal; Cannot hold heavy, strong animals.	The passive arm may deter animal from entering the box; Moving arm may stress the animal;	Does not restrict all movement; Bar may be needed across the top of the box; Rump push may be needed to position the animal (power would be required).

4.2.1 Rotary casting pens

Rotary casting pens are designed so that the animal is turned on their side or back prior to slaughter. They are generally employed as a restraint for slaughter without stunning methods (34;38-40). However, these restraints have been banned in several EU Member States, for example the UK, Sweden and Denmark. In contrast, in the Netherlands a rotating casting pen is obligatory for slaughtering cattle without previous stunning (41). In the UK the use of these pens was banned on animal welfare grounds, as the rotation of the pen to place the animal on its back adds an additional stressor in comparison to upright restraint methods (38). The Welfare of Animals at the time of Killing (England) Regulations 2012 (12) require that all stun boxes are suitable for restraining cattle in an upright position, as bovines must remain upright at all times, until unconsciousness has been verified (42). Any ruminant placed on its back suffers gross discomfort due to the weight and size of the rumen with its contents pressing upon the diaphragm (43). In addition, the lack of adequate braking system, which can result in the pen swinging through more than 180° and rocking backwards and forwards before stabilising can increase the level of stress in the animal. This can be followed by forcible extension of the neck, often resulting in the animal banging its head on the floor (44). The European Commission presented a report to the European Parliament, in December 2012 on systems restraining bovine animals by inversion or other unnatural position in comparison to systems that maintain the animal in the upright position; taking into account animal welfare aspects as well as the socio-economic implications, including their acceptability by the religious communities and the safety of operators(28).

4.2.2 American Society for the Prevention of Cruelty to Animals (ASPCA) pen

The ASPCA pen is a viable alternative to the standard shackling and hoisting method (45). The ASPCA pen allows the animal to remain upright with the chin lifted for easy slaughter. Grandin (34;36;46-54) has described using the ASPCA restraint pen to minimise animal distress in kosher slaughter. The ASPCA pen (Figure 14) work as follows:

Cattle enter the pen from a conventional race. A guillotine gate closes behind the animal, moving it forward by means of a wedge-shaped rump-push attached to the gate, until its head projects from the opening at the opposite side of the pen. It is secured by a neck yoke and belly plate, which travels up from the floor to lift the underside of the body. Thus, cattle are restrained in an upright position with the neck exposed in a suitable position for incision of the throat from below. As soon as the cut has been made, the side gate is raised and the shackler has ready access to the animal's hind leg. The belly plate, which takes the weight of the animal beneath its brisket, and the back plate which moves it forward so that the head is properly positioned in the chin lift are such that following the incision, the animal is fully supported as it collapses and does not fall onto the wound so long as it remains in the pen. When bleeding is sufficiently advanced, the yoke, chin-lift and belly plate are released and the carcass is pulled out of the pen by the hoist, transferred to the overhead rail and moved forwards to the dressing line. The guillotine gate, wedge, yoke, plate, chin lift and side gate of the pen are all pneumatically operated and controlled by an operative standing at a control panel on the opposite side of the pen to the side gate.

To ensure the welfare of animals slaughtered using the ASPCA pen vertical travel of the belly lift should be restricted to 28 inches (71 cm) so that it does not lift the animal off the floor (46). The rear pusher gate should be equipped with either a separate pressure regulator or special pilot-operated check valves to allow the operator to control the amount of pressure exerted on the animal (The ASPCA design has been criticised as it is possible to apply excessive pressure to the thoracic and neck areas of cattle (55)). The pen should be operated from the rear toward the front. Restraining the head is the last step. The operator should avoid sudden jerking of the controls. Many cattle will stand still if the box is slowly closed up around them, and less pressure will be required to hold them (54). Similarly, cattle will voluntarily place their heads in a well-designed head restraint device that is properly operated by a trained operator (46).

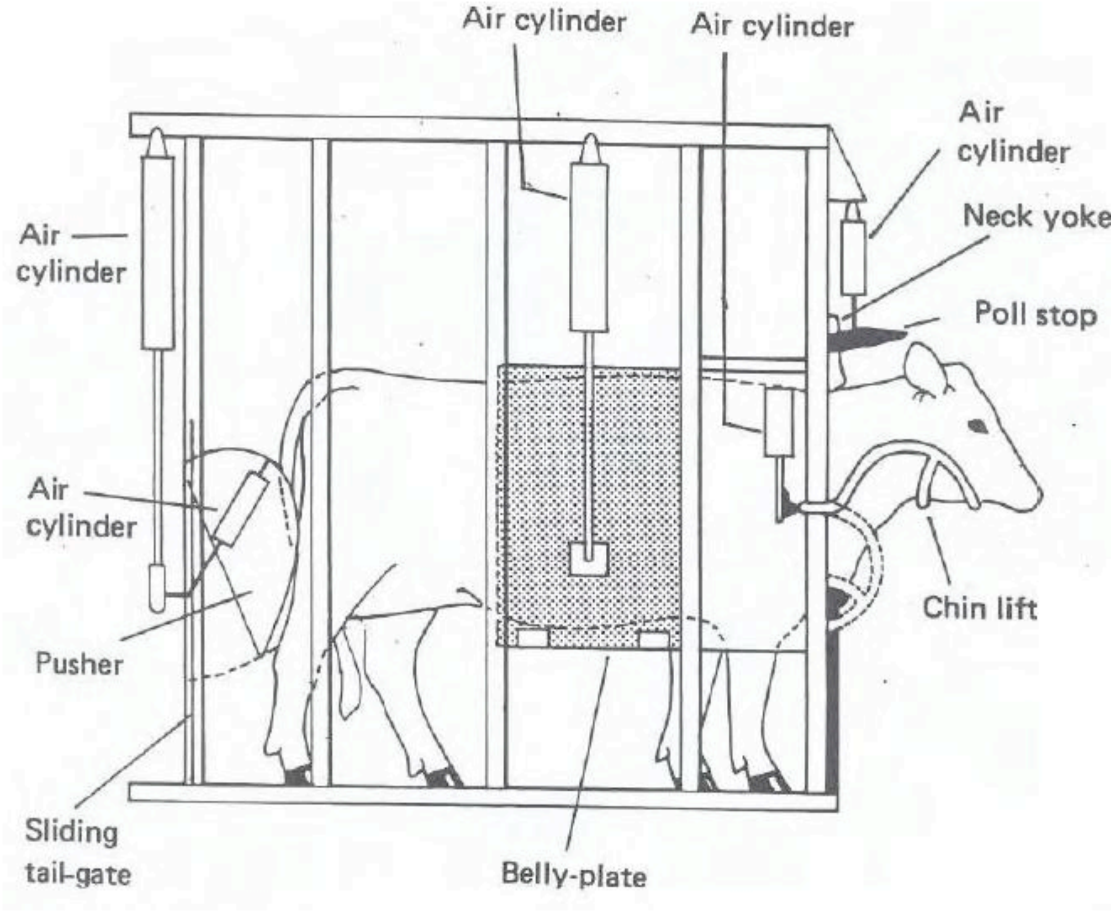


Figure 14 ASPCA pen (46)

The aim of this system is to provide suitable restraint and support for animals killed using religious slaughter methods. As such, it is typically used during slaughter without stunning. However, there is the potential for this equipment to be used with cattle that will be stunned by sticking the animal while it is in the stunning pen and then shackling and hoisting after it is dead. This would improve operator welfare by removing the need to shackle an animal during the tonic-clonic phase immediately after stunning. It should be noted that this system has not been observed in operation and its suitability as a restraint would be dependent on the individual circumstances of each abattoir. Further research is recommended as to the potential of the ASPCA or a similar design in reducing the risk to the operator from kick injury while shackling and sticking.

4.2.3 Conveyor restraint system

Grandin has also developed a conveyor system for the restraint of cattle during religious slaughter (36;46;53;54;56-59). There are two types of conveyor restraints, the V restraint and the centre track system. The animals walk down a non-slip ramp on a 25° angle and a stationary leg spreader, located over the entrance, guides the animal's legs to the correct position on the conveyor. The conveyor is constructed from metal segments attached to a moving chain. Each segment is bent to form the double rail configuration. A variety of conveyor widths can be used to accommodate the brisket of different sized animals. For adult cattle, the width of the moving conveyor is 30cm (12 inches).

The centre track system provides the advantages of easier stunning and improved ergonomics because the stun operator can stand closer to the animal. Either type of restraint system is much safer for workers than a stun box. Grandin recommends that restraint conveyors are used in all plants which slaughter over 100 head per hour. Stun boxes are difficult and dangerous to operate at higher speeds. In a plant, which slaughtered 160 cattle per hour, replacement of multiple stun boxes with a conveyor restraint reduced the serious accident rate. In 2008, centre track conveyor restraints were in over 25 plants in the USA, Canada and Australia and half of all cattle in the USA and Canada were handled in this system when they went to slaughter (59). Even though this method was originally designed for kosher slaughter, most of the centre track systems are being used for regular slaughter with stunning. The beef plants that use the centre track restraint slaughter over 40,000 cattle per day.

4.3 MECHANICAL STUNNING (CAPTIVE BOLT GUN)

Captive-bolt stunning is one of the most efficient and commonly used methods for stunning cattle (60) and is currently the best method available for stunning cattle and calves from an animal welfare perspective (27). To maintain welfare standards, most cattle in the United Kingdom are stunned with a captive bolt gun (CBG) before slaughter (61). There are two main types of CBG:

- **Non-penetrating CBG:** There are various non-penetrating devices, ranging from, the sledgehammer or maul to a mushroom headed CBG (knocker). The knocker is the only non-penetrating device that should be used in practice, as unlike manual methods, it is designed to apply a controlled blow to the head of the animal. The use of non-penetrating CBG is restricted under 1099/2009 (28) to animals of 10 kg, effectively prohibiting their use on cattle.

- **Penetrating CBG:** Penetrating CBG are primarily used for stunning cattle; however, they can also be used for sheep, goats, pigs, deer, horses and rabbits.

Captive bolt guns became exempt from firearms licensing in February 1998 (62) following amendments to the 1968 Firearms Act (63). However, when using captive-bolt equipment for the routine culling of livestock, [in the course or furtherance of a business], it is necessary for the operator to hold a current slaughter licence (42).

Captive bolt devices are activated either by trigger or by contact with the animal's head. The bolt in a CBG is propelled forward by compressed air or the expansion of an explosive charge held in a blank cartridge. Following penetration, the bolt is returned back into the barrel by the action of the recuperating sleeves (buffers). Penetrative captive bolt stunners are more effective than non-penetrating captive stunners that have a mushroom shaped head (49). There is less margin for error with non-penetrating captive-bolt stunners and the shot must be exactly on target to render the animal instantly insensible (49). The application of a blow from a penetrating CBG produces two main effects:

- Concussion is produced when the bolt impacts the skull (64). Concussion is normally defined as the reversible loss of consciousness (32), which is why mechanical stunning should always be followed by a killing method, e.g. exsanguination (65); and

- Physical damage produced when the bolt enters the brain, including, severe lesions of the brain stem and caudal portion of the cerebral hemisphere (30;66-76).

The two key elements of mechanical stunning that are required for effective induction of concussion are the positioning of the blow (shot position) and the amount of energy transferred to the animal's brain (force of impact) (32).

4.3.1 Gun type / cartridge strength

The effectiveness of captive bolt stunning in obliterating electrical responses in the cortex of the brain depends on the velocity of the bolt (77). Bolt velocity and mass are important because they determine the force of the impact of the bolt on the head of the animal and the amount of energy transferred to the brain (kinetic energy). High bolt velocity causes a concussion that induces instantaneous insensibility (67;68;78). Bolt velocity can be affected by a number of factors, including gun type and conditioning and choice of cartridge. Cartridge strength is expressed in terms of grain size, where 1 grain is the equivalent of 0.0648g of propellant. It is essential that the cartridges are appropriate for the type of device and the animal being stunned (Table 7 shows the recommended device type and cartridge strength for a variety of species). Using cartridges of lower strength than those recommended by the manufacturers can increase the incidence of poor stunning (24).

Table 7 Recommended cartridge strength (based on manufacturers specifications) (32)

Animal size & species	*Device type*	*Calibre*	*Cartridge grain*
Very large (heavy bulls)	Penetrating	.22	4.0-4.5
	Penetrating	.25	4.0
	Non-penetrating	.25	6.0
Large (large cattle, horses)	Penetrating	.22	3.0-4.0
	Non-penetrating	.25	5.0
Medium (other cattle, pigs, goats)	Penetrating	.22	2.5
	Non-penetrating	.25	4.0
Small	Penetrating	.22	1.25

4.3.2 Shooting position

The objective of mechanical stunning methods is to induce immediate unconsciousness by the administration of a severe blow to the head of the animal (32). The unconsciousness produced should "render the animal immediately insensible to pain and to ensure that it remains unconscious until it is dead" (6;79). A critical factor for successful mechanical stunning is the application of the blow to an area of the head where it will have maximum effect in causing brain dysfunction (32). The ideal position is affected by species animal age and the type of device used (i.e. penetrating or non-penetrating), but is usually to the front of the head and perpendicular to the bone surface (31).

Figure 15 Shooting position for cattle(32)

Figure 15 shows the correct position for an accurate stun when using a CBG to stun cattle. In cattle, the ideal point of shooting is in the middle of the forehead, at the crossing point of two imaginary lines drawn between the middle of each eye and the centre of the base of the opposite horn, or to a point slightly above the opposite ear in hornless animals (29). When the correct shooting position is applied, the captive bolt penetrates the cortex and midbrain areas where the physical damage can preclude recovery (30;66;67;71-76). Daly (80) studied stun effect in more than 2,500 cattle and found that effectiveness depended on the type of animal and accuracy of shooting position; in particular bulls were more difficult to stun than other cattle classes.

Evidence shows that when the correct position is not achieved the stun may be ineffective. For example, Gregory, Lee and Widdicombe (64) found that when the shooting position in the frontal plane of the head was more than 2cm from the ideal position, there was a greater risk of shallow depth of concussion and return to sensibility. Similarly, the accuracy of the stun can significantly influence the intensity of post stun convulsions. Marzin et al (81), assessed efficiency and quality of stunning in 500 commercially slaughtered cattle. The percentage of cattle that collapsed with a single shot was 93.2%, with 24.6% of cattle showing a righting reflex (trying to stand). Movements of limbs after the collapse and in the bleeding area were observed in 43.8% and 46.2% respectively and the site of impact was significantly associated with the intensity of post-stun convulsions.

4.3.3 Successful stun

In each of the methods that are used for stunning and slaughtering animals, there should be a means of verification that the processes were carried out adequately (32). “Successful” does not mean that these stuns are irreversible or that the animal was killed, but that the animal is rendered insensible between stunning and death through exsanguination (stun-stick interval) (82). Successful captive bolt stunning is normally associated with tonic spasms in the body followed by a variable amount of clonic activity, i.e. kicking (83). However, more than one sign should be considered when assessing stunning efficiency as it will increase the likelihood of differentiating between efficient and inefficient stunning (84). The criteria commonly used for assessing effective stun and depth of concussion are as follows (32;64;84):

- The animal collapses immediately and does not attempt to stand up (absence of righting reflex);
- The body and muscles (dorsum and legs) of the animal become tonic (rigid) immediately after the shot;
- Absence of normal rhythmic breathing;
- Absence of corneal reflex, i.e. the eyelid is open with the eyeball facing straight ahead and is not rotated;
- Absence of painful responses (ear or nose pinch); and
- Absence of vocalisation.

Similarly, rhythmic breathing, presence of the corneal reflexes (nystagmus), righting reflexes, vocalisations, response to painful stimuli and presence of ear muscle tone are indicative of an ineffective mechanical stun and that there has been a return to consciousness (32;85;86). A study by Gouveia, et al. (84) reported that, overall, the most frequent indicators of inefficient stun were the presence of muscle tone in the ears (17.8%), absence of muscle spasms (11.5%), presence of rhythmic breathing (9.4%) and vocalisation (7.9%). The parameters indicative of inefficient stunning that appeared more commonly among animals that presented signs of return to sensibility were absence of immediate collapse (100%), presence of rotated eyeballs (91.3%), presence of rhythmic breathing (91%) and painful response to ear and nose pinch (84.6%).

The best slaughter plants under the best conditions average 97-98% successful stuns (50). To pass a welfare audit, the first shot must instantly induce insensibility in 95% of the cattle (and 99% for an excellent score (53)). Audit data collected in both the US and Europe shows that the 95% level is easily attainable. For example, Grandin (48;57) assessed stunning efficacy in 19 beef plants, measured as a percentage of cattle rendered insensible (absence of rhythmic breathing, vocalisation, righting reflex, eye reflexes) with one shot from a captive bolt, and reported that 21% of these plants had a perfect score of 100% for stunning efficiency. Grandin (86) subsequently demonstrated that in a controlled slaughterhouse environment, approximately 1.2% of bulls and cull cows returned to sensibility after captive bolt stunning, prior to being hoisted onto the rail. Similarly, Atkinson and Algers (24), examined the quality of stun in 2700 cattle across 5 Swedish abattoirs. No abattoir had a 100% success rate; at the best performing abattoir 98% of cattle were effectively stunned. Overall, 92% of all cattle observed were considered effectively stunned. Reasons for failure to stun properly were; shooting outside of the effective stun area on the head, use of unclean or un-serviced guns (with worn out parts) and the use of damp ammunition. A similar study conducted by Gregory, et al. (87) in UK abattoirs found that 6.6% of 1284 steers and heifers were stunned poorly; 1.7% of 628 cull cows were stunned poorly and young bulls appeared to be particularly hard to stun correctly with 53.1% of 32 bulls in the study stunned poorly.

A number of factors can affect the efficiency of stunning. For example, Gouveia, et al. (84) reported an overall efficiency of captive bolt stunning of 68.2% (N = 850). The efficiency of stunning decreased substantially with age, ranging from 89.1% in cattle younger than 12 months old, to 50.3% in cattle aged 30 months or over. Certain anatomical changes are known to occur in the bovine skull during growth that could possibly explain this finding. The frontal sinuses are less developed in calves compared to adult cattle and this development tends to follow the growth of the animal, invading the dorsal aspects of the skull (88). As adult cattle present a larger and thicker frontal bone, in some animals the brain might be beyond the normal reach of the bolt. Similarly, significant differences in stunning efficiency were also observed between male (75.6%) and female (63.1%) cattle, and by breed. Stunning efficiency was greater in dairy (74.3%) compared to beef cattle (62.2%), this finding was observed for all age groups considered. As with the effect of age, the differences in stunning efficiency found between breeds may be associated with skull development. A similar finding was reported by Atkinson and Algers (24), who found that bulls were more difficult to stun than other cattle even if shot correctly (up to 11%). This was attributed to the use of underpowered weapons for the thickness of bulls' skulls.

4.4 TONIC – CLONIC PHASES

Stunning methods induce temporary loss of consciousness and rely solely on prompt and accurate sticking procedures to facilitate bleeding and cause death (89). The physical response to effective stunning is the immediate onset of tonic-clonic seizures (27). The two distinct phases are characterised by:

- The tonic phase, in which the animal falls to the floor and lies still and rigid with its head raised, front legs extended and hind (rear) legs tucked up into the body. The tonic phase typically lasts 10 to 25 seconds.

- In the clonic phase, if the animal is not slaughtered, uncontrolled convulsions or kicking movements take place from 15 to 45 seconds (7-9).

Associated with the physical responses, the brain undergoes a series of chemical changes (90). Efficient stunning methods disrupt the neurons or neurotransmitter regulatory mechanisms in the brain, causing a long-lasting depolarised neuronal state that renders the animal unconscious and insensible (27). In particular, there is an increase in the concentration of the amino acid [excitatory] neurotransmitters glutamate and aspartate in the brain (91). These neurotransmitters contribute to the development of epileptiform-like activity, which is accompanied by tonic (tetanus, rigid extension of legs) and clonic seizures (leg-kicking). This is followed by the release of another neurotransmitter GABA (gamma-Aminobutyric acid) that assists in the recovery if the animal is not killed (90-92).

If an animal fails to show tonic seizure i.e. the muscles are flaccid immediately after stunning and instead immediately shows paddling or kicking movements on collapse, it is likely that stunning has not been effective and the animal should be re-stunned immediately (79). Otherwise, there is a risk that the animal will regain consciousness (8). During both of these phases no rhythmic breathing should be evident (93). If the animal is not slaughtered, a quiet phase sets in; breathing restarts, and the animal shows signs of regaining awareness, i.e. a return to sensibility.

Table 8 Summary of the tonic and clonic phases

Tonic phase	*Clonic phase*
Animal collapses and becomes rigid	Gradual relaxation of muscles
No rhythmic breathing	Paddling or involuntary kicking
Head is raised	Downward movement of eyeballs
Forelegs extended and hind legs flexed	Urination and/or defecation

Risks for human operators may be directly related to the stunning or killing method. The presence of the convulsions, occurring after the application of certain stunning or killing methods is a hazard, particularly when slaughtering large stock. The hind-leg kicking associated with the clonic phase can occur even when brain function is depressed by a correctly applied and effective stun (94). Thus, from an operator welfare perspective, the beast should be shackled and hoisted soon after stunning and sticking should be performed whilst the animal is still in the tonic phase and the hind legs are still doubled up into the body (in flexion) (27). This makes the cut easier to carry out and helps protect the slaughter personnel from kick or knife injury (95).

4.5 SHACKLING AND STICKING

4.5.1 Shackling

One of the basic principles of hygienic slaughter is to lift the carcass off the floor at the earliest possible stage (25). During traditional line slaughter the animal is shackled and hoisted onto the bleed rail as soon as possible after it is stunned. Figure 16 shows a three-dimensional computer model that is intended to represent the standard slaughter process encountered during the course of this project. The model was created using an ergonomics design and evaluation programme, Jack (version 7.1, Siemens Product Lifecycle Management Software Inc.). Jack can be used to generate scaled human mannequins of known anthropometry. In each of these models the human is representative of a 50th percentile male worker. Figure 16 shows the operator shackling the back leg of the animal ready for hoisting onto the bleed rail. The environment is modelled to represent the dimensions of the typical killing floor lay out; no modifications are shown. The shackle is usually applied above the tarsus (hock). Applying the shackle at this point will prevent the animal's hind leg from becoming detached from the shackle and the animal slipping out, as the tuber calcanei (the point of the hock) serves to lock the shackle in place. Once the shackle is applied the operator raises the animal by means of a hoist and transfers it to the bleed rail.

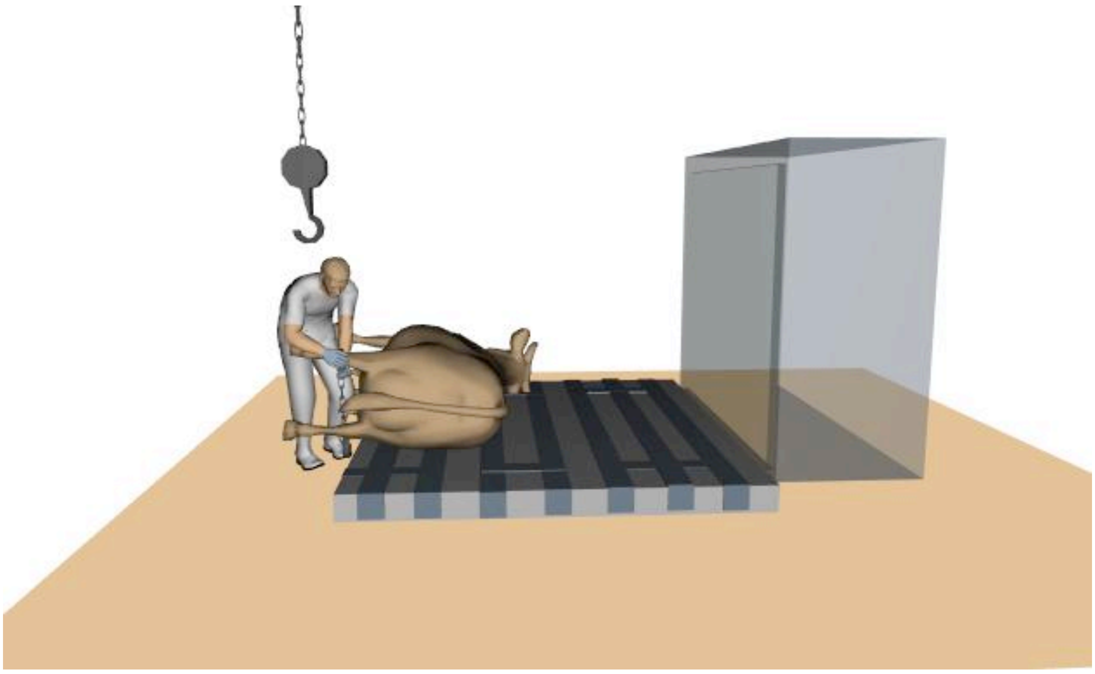


Figure 16 Standard shackling task

4.5.2 The kick envelope

The kick envelope is a 3-dimensional representation of the space within which the slaughterman (representative of a 50^{th} percentile male worker) works while performing a. the shackling task and b. the sticking task. Figure 17 shows the kick envelope during the shackling and sticking tasks. The limits of the envelope are determined by the functional reach of the animal's limbs, which in turn are dictated by the anatomical structures of the animal and the presence / absence of tonic-clonic activity. The envelopes shown here have been based upon the experience gained during the site visits. The environment is modelled to represent the dimensions of the typical killing floor lay out; no modifications are shown. The kick envelope, highlighted in red, shows that the shackling and sticking tasks require the slaughterman to work predominantly within the kick envelope. This represents a high level of risk to the operator should the animal kick during slaughter. In terms of risk reduction the task should be designed to minimise the time spent within this zone. Further work is recommended to refine the kick envelopes. Kick envelopes should be designed with the largest cattle in mind (e.g. 30 month old, Chianina, bulls), so as to account for the activities with the greatest level of risk. Further measurement / observation would allow more accurate modelling of the kick envelope.

a.

b.

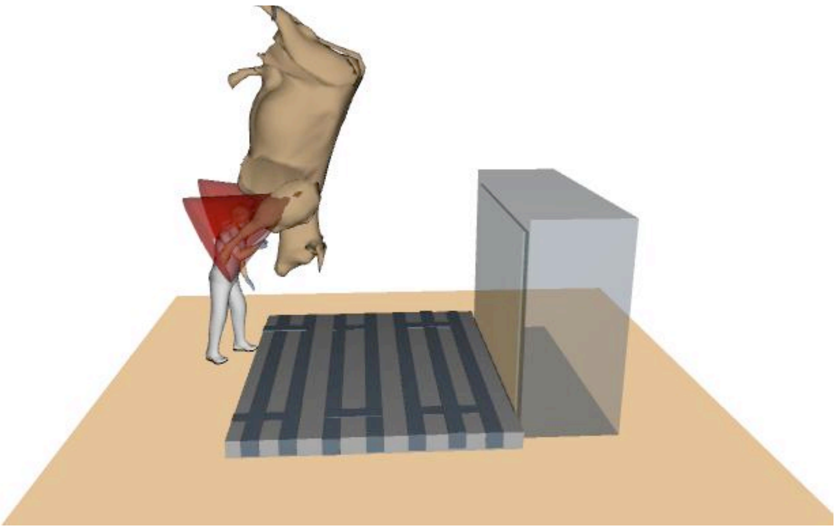


Figure 17 Kick envelopes during the standard shackling and sticking tasks

4.5.3 Sticking methods

Bleeding is the part of the slaughter process where the main blood vessels of the neck are severed in order to allow blood to drain from the carcass, resulting in the death of the animal from cerebral hypoxia (96). From the point of view of animal welfare, animals that are stunned with a reversible method should be bled without delay (ideally within 60 seconds) (31). The knife that is used must be clean and sharp and of sufficient length for the species and size of the animal (32). A blunt knife will prolong the incision and the cut ends of the blood vessels can become damaged. This may cause premature clotting and blockage of the vessels, delaying bleeding out and prolonging the onset of unconsciousness and insensitivity. Incisions should be swift and precise (96). Two types of stick are applicable for cattle (32):

- **Thoracic (chest) stick** – Make a 30-cm longitudinal cut in the jugular crease at the base of the animals' neck between brisket and jaw. With the knifepoint at the base of the breastbone and pointed towards the chest, insert a second knife at a 45° angle in order to sever the jugular and carotid vessels coming from the heart.

- **Ventral (neck) stick** – Insert a knife, close to the head, cut through the neck (with the back of the knife against the spine), cut forward severing all the soft tissues between the spine and the front of the neck (97). Reverse the blade and cut back against the spine. This action will sever both the carotid arteries and both jugular veins. The incision also transects skin, muscle, trachea, oesophagus, sensory nerves and connective tissues (98).

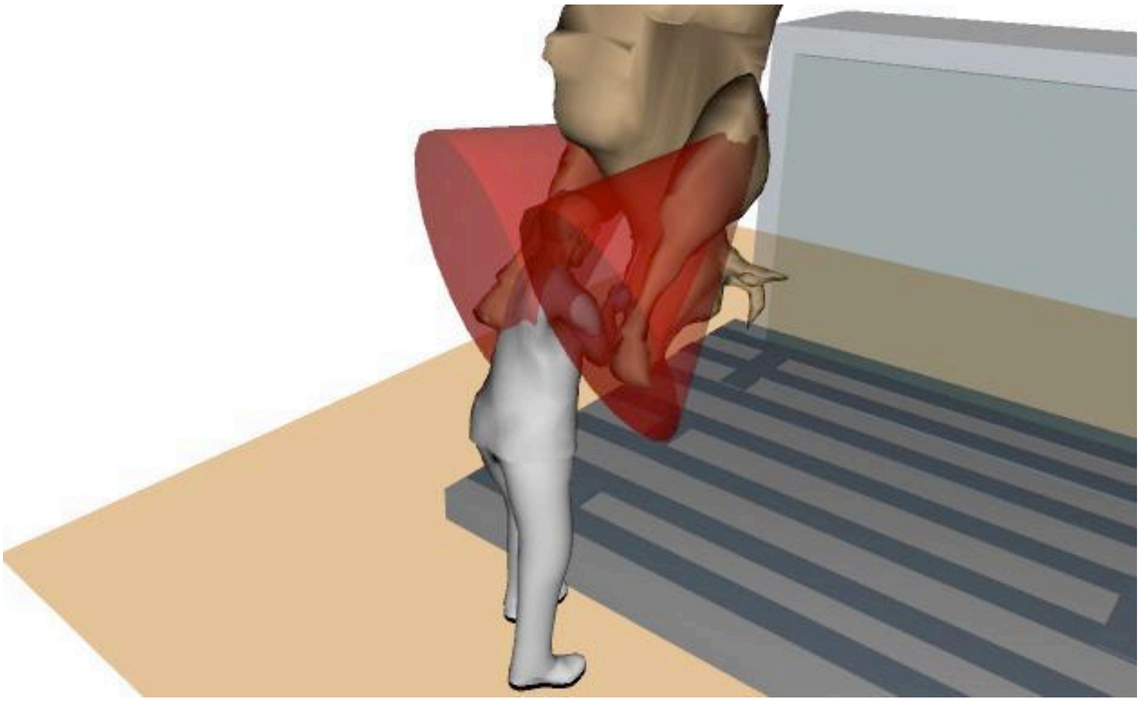
The use of either a neck cut or a thoracic stick should result in a swift and permanent fall in blood pressure and lead to rapid loss of blood supply to the brain leading to death (27). The effects of stunning and the reduction in blood flow due to the slaughter cut combine to hasten brain death (99). Regardless of the type of cut, the jugular and carotid vessels should be completely severed and bleeding should continue for 5-6 minutes. The average amount of blood obtained from cattle is around 13.5 litres (93). Following sticking the animal must be allowed to bleed to death before any further dressing procedure is carried out. The minimum times are 25 seconds after sticking pigs, sheep and goats, and 60 seconds for cattle and deer (32). Delayed bleeding will result in an increase of blood pressure, causing blood vessels to rupture, muscle haemorrhage and excessive retention of blood in the tissue, which will cause the meat to decompose more quickly (96).

A chest stick is preferred for optimum welfare assurance when slaughtering cattle. Cattle have significant blood supply to the brain through the vertebral arteries, which are not affected by a throat cut (95). The basi-occipito plexus continues to supply oxygenated blood to the brain through an alternative route to the branches of the carotid arteries (100), which can delay cerebral hypoxia during occlusion of the carotid arteries (101-104); prolonging the duration of sensibility after stunning (105;106) and during slaughter (107;108). This may be exacerbated by the fact that cattle are also more prone to develop false aneurysms[5] in the common carotid arteries when those arteries are severed during slaughter following stunning (110). The combination of false aneurysm formation in the carotid arteries plus collateral blood flow through the plexuses presents a theoretical risk of recovery of consciousness during slaughter following reversible stunning methods (107;111;112). Therefore, the chest-sticking technique, by cutting the brachiocephalic trunk or main vessels arising from the heart, is more efficient (27;107). Alternatively, a neck cut followed by a thoracic stick performed rapidly after the stun should reduce the chance of return to sensibility issues (113).

[5] False aneurysm occurs when blood is retained in the surrounding tissues by a barrier of coagulated blood between the outer surface of the artery and the inner aspect of the connective tissues surrounding the artery (109).

However, from an operator welfare perspective the use of a ventral-neck stick offers more protection for the operator, as they are able to approach the hanging animal from the side using the non-knife hand to steady the carcass, while the knife hand is used to make the incision.

a.



b.

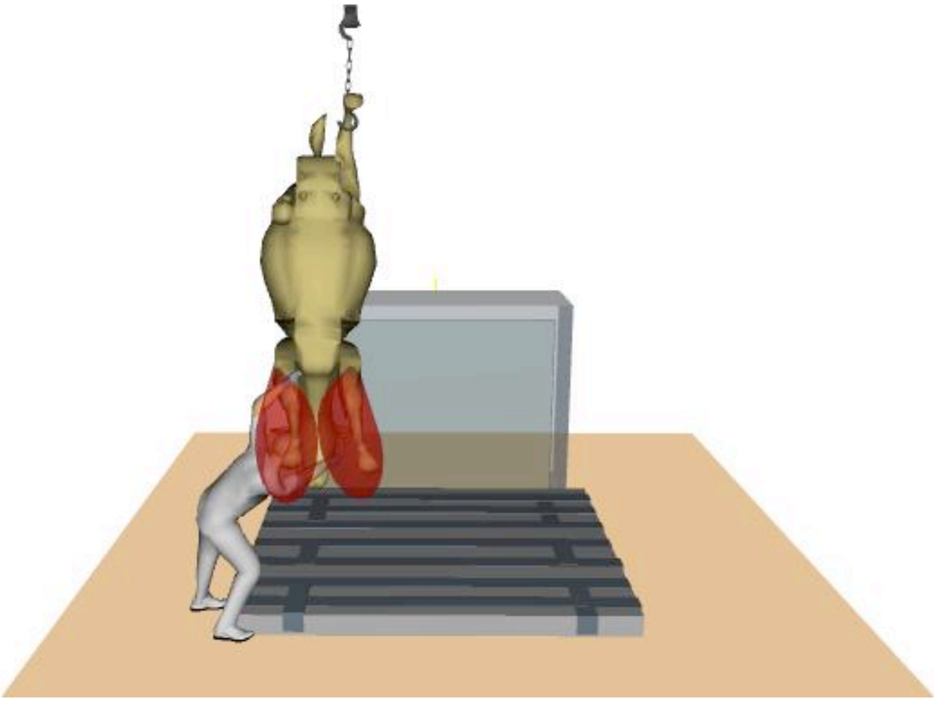


Figure 18 Jack models of sticking a. thoracic and b. ventral-neck

Figure 18 shows JACK models of both a thoracic and ventral-neck stick. As can be seen in Figure 18a the thoracic stick requires the operator to work within the likely kick envelope, increasing the chances of being kicked by an animal exhibiting clonic activity. Figure 18b (ventral-neck stick) shows that the operator is able to stick the animal without having to enter the area between the animal's front legs. The operator would still have to be aware of the possibility that the animal could thrash around on the chain, which may place the operator in danger of being caught by the animal's head as it moves. This would be exacerbated should the operator be caught between the animal and a hard surface such as a wall. However, the fact that the operator can use the non-knife hand to hold the front leg of the animal means that there should be some forewarning that the animal is about to move.

4.6 STUN TO STICK TIME

Stun-to-shackle and stun-to-stick intervals were recorded using a stopwatch and analysed for minimum, maximum and average time intervals. For cattle the start of the stun was timed as soon as the shot was heard from the stun gun, while sticking was considered to be the point at which the knife was pushed into the throat of the animal for bleeding. Also recorded was the number of times each animal was shot and any incidents or stops in the system between stun to stick.

Table 9 Average stun-to-stick times for different abattoir throughputs

Abattoir size	*N (cattle)*	*Stun-to-shackle*	*Stun-to-stick*
Large	175	22.32 (SD ± 8.75) (Range 8.0 – 95.2)	65.21 (SD ± 17.25) (Range 25.0 – 151.3)
Medium	120	18.95 (SD ± 6.11) (Range 8.1 – 49.3)	51.95 (SD ± 12.72) (Range 29.1 – 150.1)
Small	3	26.8 (SD ± 3.22) (Range 23.4 – 29.8)	75 (SD ± 13.75) (Range 59.4 – 85.4)

The time interval between stun to stick should be within 60 seconds (27;32;42;47;49;79). However, results indicate that few abattoirs can consistently achieve stun to stick intervals within 60 seconds (Table 9).

4.6.1 Shackling

During the site visits each animal was subjectively assessed for the degree of post-stun [clonic] convulsions and activity during the shackling task, using the scoring system described in Table 1. Figure 19 shows the overall percentage of animals that kicked while the shackle was applied. 70% (206) of the 298 animals observed showed no post stun activity during the shackling task. Of the 30% (92) that did exhibit kicking behaviour, the level of moderate (12%, 37) and severe (3%, 10) activity is of most concern to the operator as this is the proportion that could lead to injury.

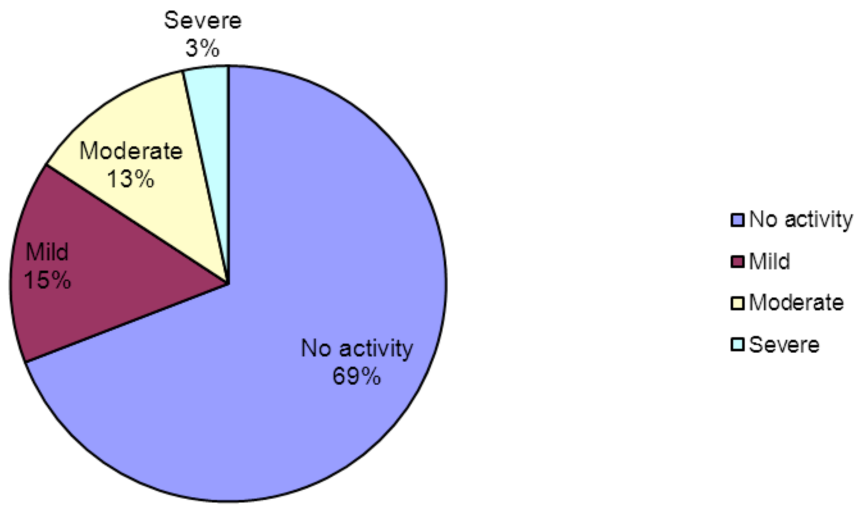


Figure 19 Overall % of cattle observed to kick during shackling

Figure 20 shows the percentage of animals that kicked while the shackle was applied, broken down by abattoir size (throughput). 68.6% (120) of the 175 animals observed in large throughput abattoirs showed no post stun activity during the shackling task. 14.9% (26) registered mild activity, 12.6% (22) registered moderate activity and 4% (7) registered severe activity that causes a significant delay in the operation with a concurrent danger to the operative. Similarly, 69.2% (83) of the 120 animals observed in medium throughput abattoirs showed no post stun activity during the shackling task. 15.8% (19) registered mild activity, 12.5% (15) registered moderate activity and 2.5% (3) registered severe activity. No cattle at small throughput abattoirs were observed kicking during the shackling task. However, this result is unreliable, as only one small sized abattoir was observed during the site visit phase and a relatively small number of cattle were slaughtered during the visit (three) therefore, the small-scale abattoirs have been excluded from further analysis. Results from the statistical analysis of kicking scores at shackling show that there is no significant difference in the proportion of large throughput abattoirs that experienced moderate or severe post stun convulsions during shackling, compared with the proportion of medium throughout abattoirs ($P > 0.05$, Chi-square = 0.040 with 1 degree of freedom).

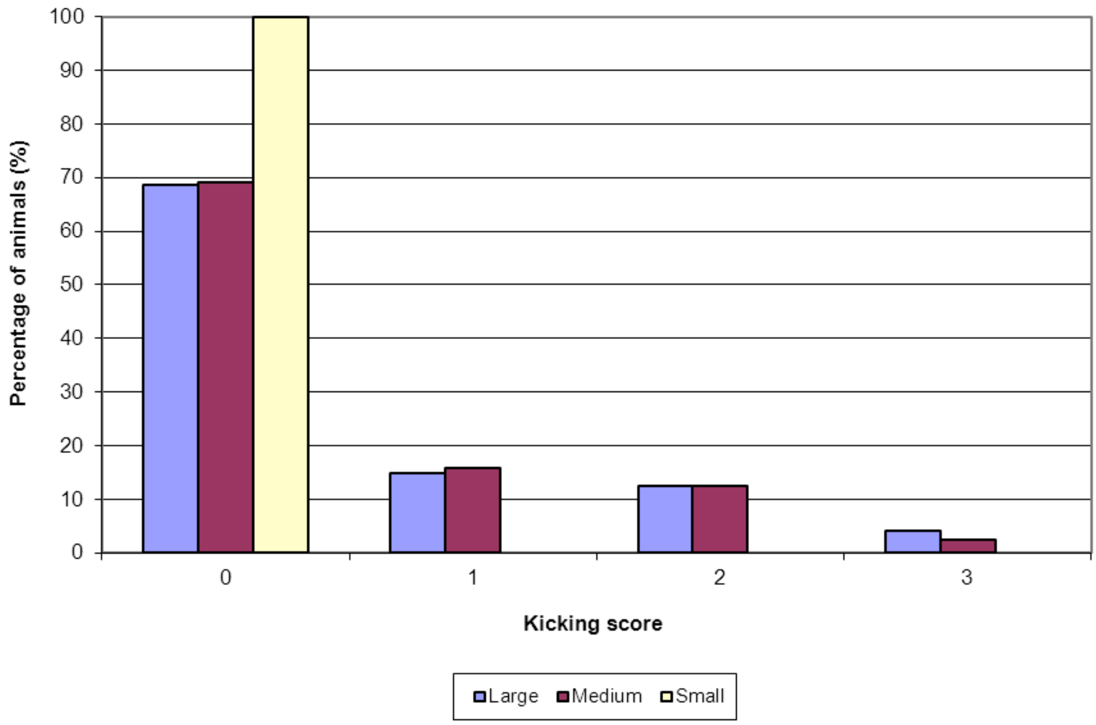


Figure 20 Average kicking scores at shackling

Table 10 Kicking at shackling

Group	*Throughput*	*Total no of animals*	*Animals within group*		*C.I. 95%*	*Range*
			N	*%*		
0	Medium	120	83	69.2	0.6917	0.6040 to 0.7675
	Large	175	120	68.57	0.6857	0.6135 to 0.7500
1	Medium	120	19	15.83	0.1583	0.1029 to 0.2349
	Large	175	26	14.85	0.1486	0.1029 to 0.2093
2	Medium	120	15	12.5	0.1250	0.0761 to 0.1971
	Large	175	22	12.57	0.1257	0.0839 to 0.1836
3	Medium	120	3	2.5	0.0250	0.0053 to 0.0741
	Large	175	7	4	0.0400	0.0180 to 0.0818

4.6.2 Sticking

During the site visits each animal was subjectively assessed for the degree of post-stun [clonic] convulsions and activity during the sticking task, using the scoring system described in Table 1. Figure 21 shows the overall percentage of animals that kicked during sticking. 90% (269) of the 298 animals observed showed no activity during this task. Of the 10% (29) that did exhibit kicking behaviour, 70% (20) was rated as mild and only 30% (9) was rated as moderate. No animal scored 3 (severe) during sticking, which reflects the fact that severe post-stun convulsions are likely to result in a significant time delay during the shackling task and under these circumstances the operator would have to wait for kicking to subside before attempting to attach the shackle.

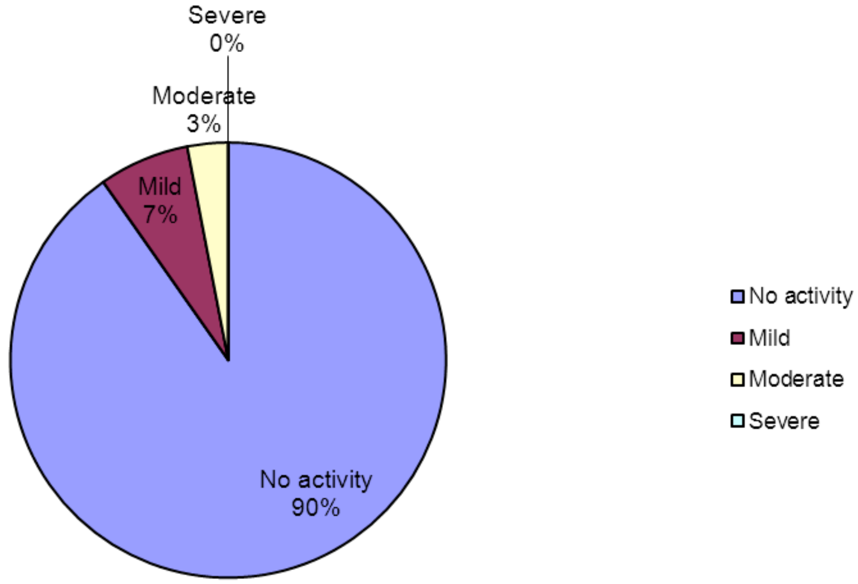


Figure 21 Overall % of kicking during sticking

Figure 22 shows the percentage of animals that kicked at the point of sticking, broken down by abattoir throughput. 88% (154) of the 175 animals observed in large throughput abattoirs showed no post stun activity during the shackling task. 9.7% (17) registered mild activity and 2.2% (4) registered moderate activity. Similarly, 94.1% (113) of the 120 animals observed in medium throughout abattoirs showed no post stun activity during the sticking task. 1.6% (2) registered mild activity and 4.1% (5) registered moderate activity. No animals registered severe activity, regardless of abattoir size, which reflects the fact that severe post-stun convulsions are likely to occur prior to shackling and would likely have subsided by the time the stick is applied. Results from the statistical analysis of kicking scores at shackling show that there is no significant difference in the proportion of large throughput abattoirs that experienced moderate or severe post-stun convulsions during sticking, compared with the proportion of medium throughout abattoirs (P = 0.5631, Chi-square = 0.334 with 1 degree of freedom).

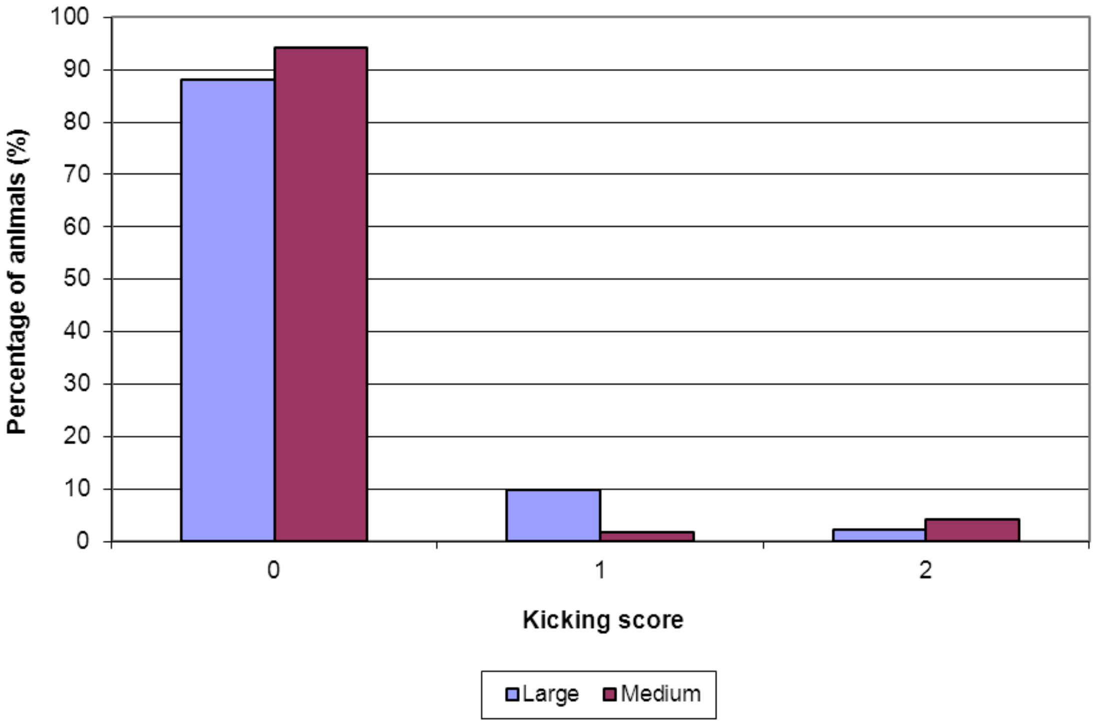


Figure 22 Average kicking scores at sticking

Table 11 Kicking at stickling

Group	*Throughput*	*Total no of animals*	*Animals within group*		*C.I. 95%*	*Range*
			N	*%*		
0	Medium	120	113	94.16	0.9417	0.8824 to 0.9735
	Large	175	154	88	0.8800	0.8228 to 0.9208
1	Medium	120	2	1.66	0.0167	0.0008 to 0.0625
	Large	175	17	9.71	0.0971	0.0607 to 0.1509
2	Medium	120	5	4.16	0.0417	0.0154 to 0.0963
	Large	175	4	2.28	0.0229	0.0069 to 0.0593

4.7 OTHER PERFORMANCE INFLUENCING FACTORS

4.7.1 Work pace and fatigue

Operator fatigue is a major cause of missed CBG shots (49) and can lead to ineffective stunning of animals and the necessity for additional stunning attempts (48). Furthermore, inaccurate stunning can increase the chance of post-stun convulsion (64;81). Where possible, abattoirs should avoid having workers perform the same task for the duration of the day by rotating teams and individuals. Workers should rotate to a job with different physical demands after performing slaughter operations, as this will provide recovery time. For example, in abattoirs that have three operatives, each performing one of the slaughter tasks (stunning, shackling and sticking), they could rotate between each of the tasks so that the risk of fatigue is shared equally throughout the shift. Regular short breaks in work are a better means of avoiding fatigue compared to infrequent longer breaks and, where possible, a flexible approach to timing of work breaks should be adopted. Provided the tasks involved are sufficiently different in character, job rotation can also be effective in avoiding the onset of fatigue as a result of prolonged use of the same muscle groups. Increasing the work pace will facilitate the onset of operator fatigue. Larger abattoirs with greater throughput are more likely to have to operate at a high work pace. Further research is required to examine the role of operator fatigue in accidents within the abattoir setting and, in particular, whether abattoirs with larger throughputs are at an increased risk of accident, when the size of the workforce and exposure are accounted for.

4.7.2 Training

It is important that all operators involved with stunning and slaughter are competent, properly trained and have a positive attitude towards the welfare of animals (27). Previously, under the Welfare of Animals (Slaughter or killing) Regulations (as amended) 1995 (42), anyone carrying out stunning, slaughtering or killing operations was required to have a provisional or Registered Slaughterman's Licence. A Registered Licence would only be issued once a certificate of competence has been obtained from the local official veterinarian (OV), which covers the operations, equipment, and species that the applicant is competent to slaughter. To obtain a certificate of competence the OV must have been satisfied that the applicant had sufficient understanding of relevant statutory requirements (including Codes of Practice) and how they work to protect the welfare of animals and have undertaken a formal assessment of the applicant's practical skills under normal working conditions.

However, the Regulations did not specify how a Provisional Licence holder should be trained. Often, the apprenticeship model was applied. The apprenticeship model is one of the oldest forms of learning by doing, wherein a novice obtains practical experience by working with and being instructed by a more senior, experienced colleague and under the guidance of the OV. Workers progressed from menial / simple tasks through to more complex elements of the slaughter / dressing process as they gained more experience. The fact that the competence of slaughtermen is based on practical skills, experience is essential and on-the-job training is likely to be most effective. However, this approach allows for the introduction of significant variation across the meat processing industry, as the quality of training received is dependent on the skills and ability of the staff from which the novice slaughterman learns. It is highly probable that different organisations could have different standards of professional practice, as would the local OV responsible for issuing the certificate of competence and this approach may serve to proliferate both good and bad practice.

Article 7(2) of Regulation 1009/2009 (28) requires every person undertaking the following operations, for the purpose of killing animals for human consumption, to hold a Certificate of Competence (CoC):

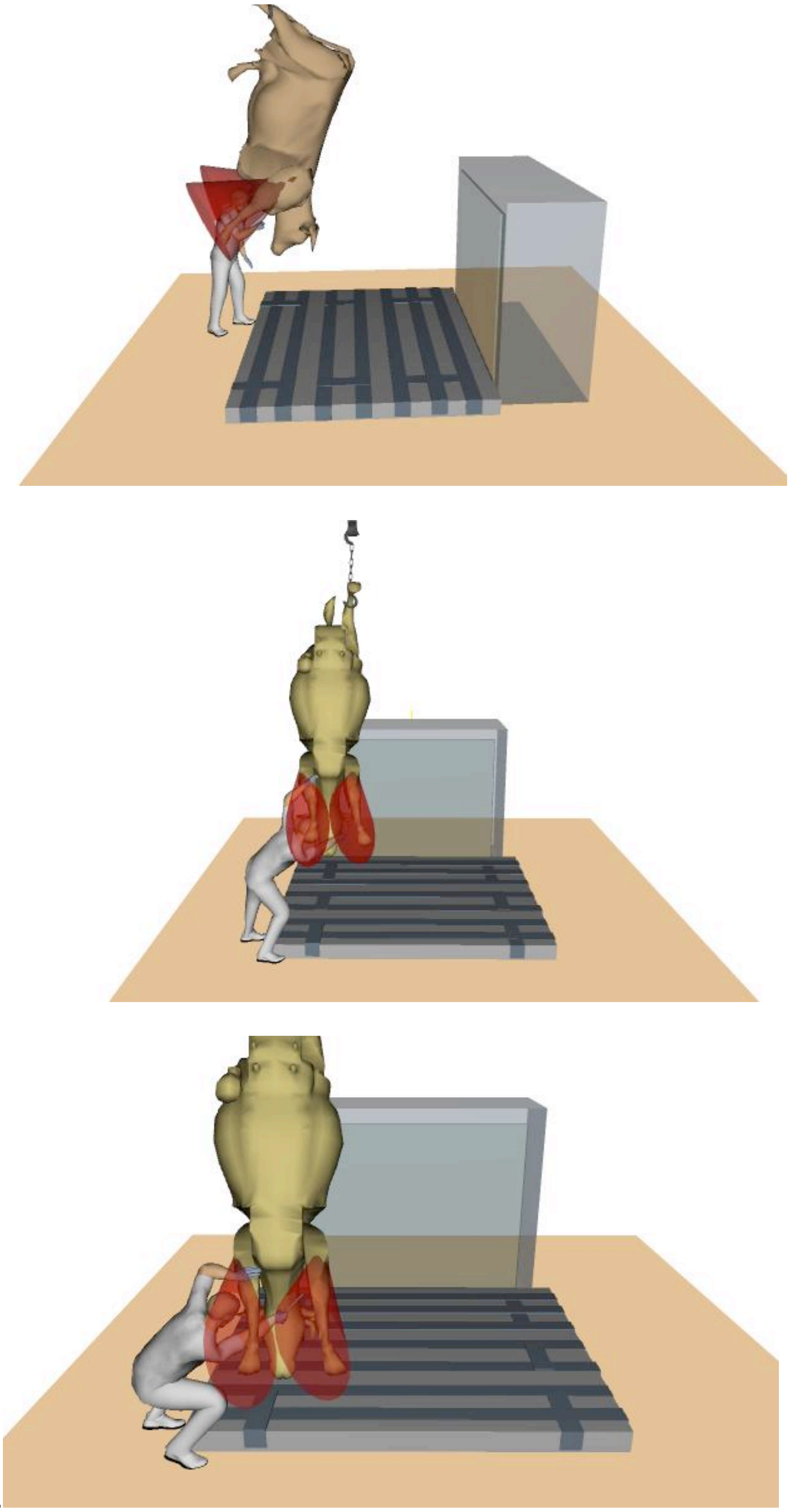
- The handling and care of animals before they are restrained;
- The restraint of animals for the purpose of stunning, slaughtering or killing;
- The stunning, slaughter or killing of animals;
- The assessment of effective stunning;
- The shackling or hoisting of live animals;
- The bleeding of live animals; and

- Religious slaughter.

Furthermore, anyone carrying out any of these tasks must have the knowledge and skill to do their job humanely and efficiently. As such, individuals who require a CoC to carry out any of the killing and related operations listed above must undergo a training course and an independent final assessment in accordance with Article 21 of Regulation 1099/2009. The Food Standards Agency acts as the Competent Authority for the purposes of issue and delivery of Certificates of Competence within England, Scotland and Wales and as such, has developed (in conjunction with Defra) an accredited Level 2 qualification in “Protecting the Welfare of Animals at Time of Killing” for this purpose, which is administered by the Food and Drink Qualifications (FDQ) and the Royal Society for Public Health (RSPH) on behalf of the competent authority. It is likely that this route will still rely heavily on the fundamentals of the apprenticeship model and a key element will be the provision of periods of on-the-job training, which provides trainees with an opportunity to develop the essential skills of the job.

4.7.3 Hoist height

In order to operate safely, abattoirs need sufficient space and height, and suitable equipment, so that stunned animals can be hoisted for slaughter quickly and abattoir workers can move around the animal safely and out of range of any kicking (114). The difficulty for many abattoirs is due to the technical design of the shackle line, in that the speed of the hoist limits the rate at which carcasses can be transferred to the sticking area. The time taken to move the animal from the initiation of the stun to sticking the animal was similar across abattoirs, regardless of design or throughput. The height of the hoist may affect the extent to which the sticking operator has to work within the kick envelope. The risk of injury is greater the more the operative is required to work within the kick envelope. Figure 23a-c show the impact of hoist height on the operators exposure to the kick envelope and the extent to which the stunned animal is capable of kicking the shackling operator. Figure 23a shows the hoist set to the mean hoist height observed during the site visits (4.23m, SD ± 1.34m, Range 1.9 – 5.23 m), Figure 23b shows the hoist set to the maximum hoist height observed during the site visits (5.23 m) and Figure 23c shows the average minus one standard deviation. This is to illustrate the impact of a low hoist. The minimum hoist height observed during the site visits was 1.9 m. However, this was not used as it fundamentally changed the slaughter tasks. With such a low hoist height, operatives were required to shackle both a front and the opposite back leg to lift the animal off the floor, the animal was bled in an almost horizontal position; a light gradient was retained in order to ensure a sufficient bleed. The animal was then placed on a dressing cradle and the hoist was used to transfer it to the dressing area where the first dress procedures (removing the hock, de-hiding, etc) were performed before the hoist was used to lift the animal onto the dress rail for further processing.



a. b. c.

Figure 23 The impact of hoist height on exposure to the kick envelope

4.8 ALTERNATIVE STUNNING METHODS

The following sections describe a number of alternative slaughter methods that appear in the research literature and discuss some of the pros and cons in relation to kicking during slaughter activities. Electrical stunning and some of the common misconceptions around its use are given extra consideration, as it has the potential to improve operator safety by eliminating the presence of post-stun convulsions. While, under optimum operating conditions there are no significant welfare or meat quality problems.

4.8.1 Firearms (free bullet)

Free bullet weapons include rifles, shotguns and humane killers (specially manufactured / adapted single-shot weapons). They are mainly used under emergency situations such as, casualty slaughter or killing for disease control (82). Free bullet fired to the brain is effective for on-farm killing of cattle, sheep, pigs and horses, through the massive transfer of energy to the brain that causes immediate unconsciousness and death(29;85). The free bullet first stuns and then kills the animal in very quick succession(115). It is suitable for animals that are difficult to handle and restrain (32;96;116) and should only be used when other methods cannot be applied (116;117). The cartridge, calibre and type of bullet should be appropriate for the species, age and size. Ideally the ammunition should fragment upon impact and dissipate its energy within the cranium (29). An animal should be killed by a single shot to a recommended anatomical position (see Figure 15). The firearm should be aimed in a direction down the neck, perpendicular to the front of the skull, and held at least 5-50 cm away from the point of impact (29;96;116;117). In some circumstances (e.g. where close range shooting is not possible), rifles should be aimed to penetrate the skull or soft tissue at the top of the neck of the animal, to cause irreversible concussion and death. There are a number of disadvantages to the use of free bullets that restrict its use in non-emergency situations, including:

- The use of free bullets in enclosed spaces or when the animals stand on hard surfaces may pose a risk to operator safety, as free bullets may exit the carcass with sufficient speed to ricochet off solid objects. Free bullets can be used outdoors on soft ground or appropriate backdrop (manure heaps, hay or straw stacks, etc) where there is no risk of ricocheting bullets. It is also necessary to make sure that no person or animal may move between the target and backdrop area;

- The risk of misfired bullets increases with longer distances from the animal. Bullets that miss the vital target organ (brain, heart) may cause injury, pain and distress and may result in a flight reaction;

- Availability of specialised expertise may be limited. Persons involved in shooting should be properly trained, competent, and licensed. Within the UK the shotgun is likely to be the most common weapon used. Shotguns hold ‘Section 2’ firearms status and operatives would be required to hold a valid Shotgun Certificate. The majority of other weapons are assigned Section 1 firearms status and would require a Firearm Certificate, which enables the holder to possess the exact calibre, number and type of weapons specified on the licence and outlines the purposes for which each may be used. The Police grant Firearm Certificates predominantly for single shot rifles of any calibre, self-loading .22 rifles (and corresponding ammunition) and muzzle loading pistol; and

- Killing of animals with free bullets completely destroys the brain and subsequent examination of the brain for diseases may be more difficult.

4.8.2 Electrical Stunning

An alternative stunning method observed during the course of this research, which has the potential to improve operator safety is the electrical stun box. The use of electrical stunning has a major advantage over other slaughter methods in terms of operator welfare; the person who is shackling the animal is safe from any reflex movements of the limbs (118;119). Electrical stunning can immediately cause unconsciousness and makes the animal insensible. However, it requires high standards of technical equipment and skilled people to perform and monitor the stun and a system to record the stunning details such as voltage, current and frequency of the current for each individual stun (89). There are currently two main manufacturers of electrical stunning equipment:

- Jarvis Engineering Technologies (NZ) Ltd (http://www.jarvisengineering.com). This system is the principal equipment used for slaughtering relatively small, grass fed cattle in New Zealand.

- Banss Germany Gmbh (http://www.banss.de/en/). This system is more complex than the Jarvis system, with exsanguination being carried out in the stun box. Specially constructed apparatus for restraint and application of the electrical stun (head, neck and brisket electrodes) allows immediate sticking while the animal is still in the box, in an upright position and before the development of tonic / clonic seizures can occur (Figure 24). After bleeding, the pen is turned to the side to shackle the hind leg and elevate the animal (118).

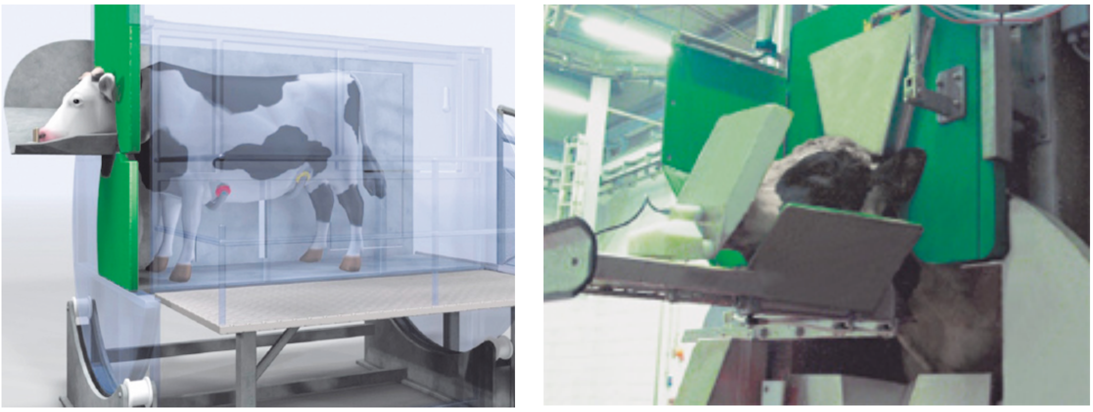


Figure 24 Banss Germany electrical stun box design (http://banss.de/en/#slaughtering-technology-cattle-stunning/)

Electrical stunning equipment can be prohibitively expensive for use with cattle, for example, a Jarvis electrical beef stunner currently retails for around NZ$ 330,000 (approximately £165,500), not including the cost of installing the electrical supply, the manual labour costs or any remedial building work associated with installation (120). This is approximately twice the cost of traditional stun box designs.

4.8.2.1 Effectiveness of the stun

Electrical stunning equipment must be capable of producing an effective stun for the species and size of the animal. Cattle are normally stunned electrically by three sequential cycles (121);

1. A three-second head-only cycle, to stun the animal;

2. A 15-second cardiac cycle, to induce ventricular fibrillation (cardiac arrest); and

3. A four-second discharge cycle, to reduce convulsions after death.

The Food and Agriculture Organisation of the United Nations (FAO) guide to good practice within the meat industry (32) recommends that electrodes are placed so that they span the brain and apply sufficient voltage (>200 volts) for ≥ 3 seconds so as to cause immediate unconsciousness. When sufficient current is applied to the brain, an epileptic fit will be produced during which the animal is unconscious.

Electrically induced head-only stuns may not last long enough to allow normal killing by bleeding and the clonic phase will be followed by the return of rhythmic breathing and subsequent recovery in an unbled animal. Cardiac ventricular fibrillation or immediate sticking while the animal is restrained will prevent recovery during bleeding (electrical stun / killing). Only procedures that lead to cardiac arrest are considered 'acceptable' on welfare grounds (119). In addition, cardiac arrest produces a still carcass that is safer and easier to bleed (122). Cardiac arrest stunning requires the use of a restraining device to prevent the animal from falling away from the stunning wand before it receives the complete stun. Head only stunning is reversible; the heart can resume normal functioning if an animal is manipulated too soon after application of the stun / killing method. Effective stunning and slaughter can be characterised by the absence of rhythmic breathing from the initiation of the stun through to the death of the animal (through correct sticking).

Electrical stunning and stun / killing devices should supply constant currents (89). Research into electrical stunning has helped define the minimum currents required to stun animals effectively. For example, Wotton, et al. (121) recommend that the minimum current to achieve a satisfactory stun is not less than 1.2 A[mps] sinusoidal AC at 50 Hz, while the current necessary to fibrillate the heart should be greater than 1.5 A (sinusoidal AC at 50 Hz), when applied for five seconds between nose and brisket electrodes. These levels were sufficient to induce epileptiform activity in the brain, identified as high amplitude low frequency activity in the electroencephalogram. The induction of effective head-only electrical stunning resulted in an average interval of 50 seconds before the return of rhythmic breathing movements, and positive corneal reflexes.

The increased reliability of electrical stunning (failure rate of <1%) in comparison to captive bolt stunning (failure rate of 1% to 5%) provides a definite advantage from a humane slaughter perspective (123). However, in some cases the use of electrical stunning equipment may result in inadequate stunning with animals showing signs of recovery (72). When the stunning electrodes are applied, the minimum current must be achieved as soon as the current starts. In addition, the current should be uninterrupted. If this does not occur there is a risk that the animal will suffer electric shock before it is stunned. It is not always easy to recognise poor delivery of current simply by examining the behaviour of the animal. Identifying poor current delivery is especially difficult in abattoirs using fast line speeds or automatic stunners. Gregory (124) examined the current profile during electrical stunning (N = 575 lambs, stunned using hand held pin electrodes or scissor type hand held tongs, and 10 head of cattle, stunned using a Jarvis Equipment Ltd Electric Beef Stunner). The current profile is the overall shape of the current that is delivered to the individual animal. Each profile was assigned to one of the five categories:

- **Satisfactory**: the current rose rapidly to a level that is known to produce an adequate stun.

- **Poor initial contact**: the current did not rise promptly; instead the animal experienced a low current for at least 0.2sec.

- **Interrupted current**: there was a break in the current during the stunning episode.

- **Failure to maintain current**: current towards the end of the stunning episode declined considerably before the current supply was switched off.

- **Spiking**: a current surge occurred at the start or end of the current application.

In general the standard of stunning was good (see Table 12). Eighty-five percent of the profiles were satisfactory, and 91% were acceptable from a welfare perspective. However, when there is poor initial contact and when the current is interrupted, there could be animal welfare problems and these types of profiles occurred in 9% of cases. If there is spiking or an interruption in the current, the body will cause repeated body spasms that rupture blood vessels, damaging the carcass. In general the standard of stunning was better in the lines that used automatic stunning. This work would need to be extended to include greater numbers of cattle to confirm whether electrical stunning equipment is acceptable for use during the slaughter of cattle on welfare, safety and meat quality grounds.

Table 12 Current profiles during stunning (Number of animals) (124)

		Profile type				
Line[1]	***Stunning method***	***Satisfactory***	***Poor initial contact***	***Failure to maintain contact***	***Interrupted current***	***Spiking***
1	Manual pin type electrodes (87)	81	3	2	1	0
2	Automatic (55)	54	0	0	0	1
3	Manual pin type electrodes (81)	40	18	1	3	19
4	Manual, head-to-back (46)	37	4	0	5	0
5	Manual, scissor tongs (306)	279	8	7	12	0
6	Automatic (10)	9	0	0	1	0

[1]Lines 1 to 5 were stunning lambs and adult sheep, line 6 was stunning cattle

Weaver and Wotton (125) investigated the effect of replacing the conventional brisket electrode with a prototype chest electrode, with, and without spinal discharge in 287 animals in a commercial abattoir. However, repositioning the electrode did not significantly affect electrical parameters in any of the electrical discharge cycles. All animals received a cardiac arrest as assessed by electrocardiogram and most post-stun / kill responses were unaffected, although the prototype electrode significantly reduced the number of haemorrhages in the sirloin. The use of the chest electrode was efficient at causing cardiac arrest, did not significantly affect post-stun / kill responses and reduced haemorrhaging in the high-value sirloin.

To ensure that the flow of current is optimal, electrodes should be well designed and constructed, cleaned regularly and maintained in accordance with the manufacturer's specifications (31). A monitoring system should be fitted that gives either an acoustic or optic signal to indicate: (a) an interrupted stun, (b) excessively short stun duration or (c) increase in total electrical resistance in the pathway (due to dirt, fleece or carbonisation), which could lead to failure (89). The advantage of stunning monitors compared to the visual inspection of animals is that they can identify problems such as pre-stun shocks, interruption in current flow at the start of stunning, and slow ramping up of the current as it is delivered (94;124;126).

4.8.2.2 Bleed quality

A cardiac arrest at the start of bleeding will slow the rate of blood loss, and in some situations it can result in less blood loss, but this is not an inevitable consequence of inducing a cardiac arrest during electrical stunning (79). For example, Velarde, et al. (127) showed that lambs that were hoisted and bled without being stunned, released less blood from the sticking wound than lambs that were electronically stunned (250V, 50Hz, 3s), hoisted and then stuck. Similarly, it has been reported that electrical stunning aids the bleed out of poultry (128-131). Raj (132) speculated that high frequency electrical stunning facilitates bleed-out through the appearance of a continuous muscular tremor that is also perceived to be pumping more blood out of the vascular system. Further research would be required to establish whether this would be the case when slaughtering cattle.

Bleeding efficiency and bleeding rate at sticking are influenced by the factors listed in Table 13.

Table 13 Factors affecting bleeding rate or bleeding efficiency at sticking (94)

Blood vessels that are severed
Size of the sticking wound
Cardiac arrest at stunning
Orientation of the carcass – positioned horizontally or vertically
Vasodilatation or vasoconstriction in the capillary bed
Tonic muscle contractions squeezing blood capillaries and vessels
Clonic activity causing movement of blood towards the sticking wound

Electrical stunning can have a positive effect on bleed quality. During conventional stunning and slaughter the carotid arteries in cattle can develop false aneurysms at their severed ends and this can curtail exsanguination (107;111;112). Cattle have an unusual anatomical feature in the cephalic blood vessels. The basi-occipitio plexuses allow blood to pass to the brain through an alternative route to branches of the carotid arteries. Blood supplied through the plexuses delays cerebral hypoxaemia during occlusion of the carotid arteries (101-104). This presents a theoretical risk of recovery of consciousness during slaughter following reversible stunning methods such as electric currents applied to the head (107).

Gregory et al. (112) have shown that cattle which were electrically stunned and simultaneously developed a cardiac arrest, do not develop false aneurysms during bleeding. Cattle were electrically stunned; using 2.1 A applied to the head followed by 1.4 A applied between the nose and the brisket (Banss GmbH). The animals were suspended vertically by leg-shackle with the head hanging downwards at 30 seconds following the cut. All the cattle that had been electrically stunned before the neck was cut had very little blood flowing from the severed arteries, confirming that they had developed cardiac arrest. The prevalence of large (>3 cm outer diameter) false aneurysms in cattle carotid arteries was 10% for both shechita and halal slaughter. The prevalence of animals with bilateral false aneurysms (at least 2 cm in one artery and at least 3 cm diameter in the opposite artery) was 7% and 8% for shechita and halal slaughter, respectively. False aneurysms did not occur following electrical stunning with cardiac arrest. This indicates the aneurysms do not form when blood pressure is suppressed, and this implies that false aneurysms are more likely to form during the early part of bleeding period in animals that have a beating heart.

4.8.2.3 Meat quality standards

The manner in which livestock are immobilised, slaughtered and exsanguinated can affect final meat quality. The method of stunning should minimise animal suffering as well as prevent excessive struggling which can result in bruising and haemorrhaging. Meat quality needs to be taken into consideration when the efficiency of the stunning system is evaluated (127). Defects such as high pH, pale, soft and exudative meat (PSE), dark, firm and dry meat (DFD), ecchymoses or petechial haemorrhages (blood splash), etc have been associated with electrical stunning in cattle (72;94). Gregory (94) identified four main theories for blood splash in electrically stunned meat:

- Counteracting muscle contractions during stunning, causing localised tearing of the capillary bed (79);

- Arterial or venous dilatation at the time of stunning may increase the likelihood of blood splash, as engorgement of the capillary bed encourages rupture of the vessels when they are placed under pressure (133).

- Blood vessels may be unduly fragile; histological examination of blood splash in meat has shown that vessels that burst are on the venous side of the capillary bed, which has less elastic walls than the arterial side and so are weaker and more prone to damage.

- During intense generalised muscle body contractions, such as those during electrical stunning, the venous and arterial systems experience severe external pressure. Squeezing of the veins results in large rises in venous pressure, which is transmitted to the capillary system at sites that can be some distance from the contractions. The venules in the capillary bed probably burst where they are weakest, or where venous pressure is particularly high.

It is not clear whether blood splash could be due to a direct effect of electrical current on blood vessels, but it seems unlikely. Electrical stimulation of tissues, even at low currents (e.g., 20µA), will promote extravasation of blood cells from the capillary bed, but this is an inflammatory response and is slower than the time available under slaughtering conditions (134). To prevent blood-splash in the meat, the electrodes must be pressed firmly against the animal so that the stunning current is supplied by constant amperage (123). Anecdotal experience has suggested that a gradual rise in the stunning current leads to less blood splash, and it is thought that sudden contraction of muscle in the body at the onset of the current can lead to tearing of the blood vessels (124).

Muscle glycogen at the time of slaughter is one of the most important factors affecting beef quality (135). Typically, blood / muscle glycogen concentrations in cattle range between 75 and 120 mmol/kg. However, this has been found to fluctuate with changes in psychological and physical responses to stress (135-138). These stressors often elicit behavioural and physiological responses, some of which can, if extreme, contribute to a reduction in carcass and meat quality (139-142). For example, Wood et al. (143) reported that extreme paleness or darkness is sometimes found in pork and beef, due to a combination of environmental and genetic factors; animals which experience stress over a lengthy period (>10 hours), usually because of mixing with unfamiliar animals or poor handling, deplete muscle glycogen stores and can develop high pH meat, which is DFD and has poor keeping quality. Alternatively, in pigs, if the stress is experienced immediately before slaughter, muscle pH falls rapidly as anaerobic metabolism occurs resulting in PSE muscle. Both of these conditions (DFD and PSE) can be avoided on many farms by the application of good management (143).

A significant body of evidence exists which demonstrates that the differences in ultimate pH between non-stunned and electrically stunned and overall meat quality are minor. This is true in a variety of species, including; lambs (127;144-146); chickens (147;148); pigs (149-153); veal (154); turkeys(155;156) and ostriches (157). However, there is limited evidence regarding the impact of electrical stunning on the quality of beef. Anecdotal evidence reported during the site visits suggests that there is little difference between beef produced from those cattle that have been electrically stunned and those that have been stunned using CBG. This is supported by Onenc and Kaya (158). They examined the effect of different slaughter methods on the meat quality of cattle during 14-days post mortem. 30 young Holstein Fresian breed bulls were slaughtered without stunning (NS), electrically stunned (ES)[6], or stunned using a percussive [non-penetrating mushroom headed] captive bolt (PS). Following stunning, cattle in all three groups were shackled and exsanguinated while hanging.

Results indicate the concentration of glycogen differed significantly according to pre-slaughter handlings. However, the rate of post mortem muscle glycolysis in electrically stunned cattle was not markedly different from that observed in non-stunned cattle. There were no statistically significant differences in colour values after stunning, but the colour was more vivid and the tone was more stable in PS than in NS and ES. There was no significant difference between meats in water holding capacity. Cooking loss increased in all groups as ageing increased. Significantly higher cooking losses were found in meats of the ES and PS groups at 7 and 14 days post mortem. This may be caused by the faster pH decline in the PS group. Texture parameters were lower in the PS group compared with the other groups. With the longer period of ageing (14 days), the meats from three pre-slaughter handlings reached similar tenderness values. PS prevents glycogen loss in cattle muscle and so improves meat texture. Textural attributes of non-stunned animals appeared lower than those of the ES group. In this study panellists gave higher scores to meats from stunned than non-stunned animals. Similarly, panellists found no differences between PS and ES steaks. For flavour, tenderness and overall acceptability, significantly more panellists preferred PS steaks to others (Blind testing), but ES steaks were as preferred as PS steaks for overall acceptability.

4.8.3 Religious slaughter

The Welfare of Animals at the time of Killing (England) Regulations 2012 (12) require that all animals are stunned before slaughter, using the methods of stunning prescribed by the Regulations, subject to specific exemptions. One of these exemptions refers to religious slaughter, provided it is done so without the infliction of unnecessary suffering and that the requirements for the licensing of slaughtermen are met. Slaughter without stunning is performed as religious rules state an animal intended for food must be healthy and uninjured at the time of slaughter (43). The use of religious slaughter methods would not reduce the level of clonic-tonic convulsions (kicking). However, both the Muslim and Jewish faiths have specific requirements for the religiously acceptable slaughter of animals (34) that represent a different approach to the

[6] Constant voltage of 400V, 1.5 amp for 10s, stunning tongs were applied on both sides of the head behind the ears (head stunning: ear-ear) (Cook, 1992). For this procedure, special electrical stunning equipment was used (voltage = 240V, frequency = 50Hz, stunning voltage = max 400V, stunning amperage = 1.5A).

commercial slaughter of animals for human consumption. It is important to understand the implications of these differences in terms of animal and operator welfare.

Jewish method of slaughter (Shechita): Slaughter is carried out by an approved slaughterman of the Jewish faith, called a shocet. A very sharp knife (chalaf) is used to make a single transverse cut that severs all tissues and blood vessels across the neck (trachea, esophagus, jugular vein, carotid artery, etc). This process when done properly leads to a rapid death of the animal (34). In the UK, a shochet must hold two licences, one issued by the Food Standards Agency (FSA) and the other by the Rabbinical Commission for the Licensing of Shochetim (159). Once the animal is dead an incision is made through the abdominal wall and a Jewish inspector feels at arms length into the thorax to check for pleural adhesions or any other signs of abnormality. If any abnormality is found, the entire carcass is rejected for Jewish consumption on the grounds that the animal was not healthy at the time of slaughter (44). As such, the slaughter process precludes any form of stunning, because an animal intended for food must be healthy and uninjured at the time of shechita. Similarly, bruises or injuries caused by the restraint methods (or from any other cause) would be objectionable to observant Jews. Some Jewish authorities allow captive bolt stunning after the neck cut (32). Where possible, this should be encouraged to protect animal welfare.

Muslim method of slaughter (Halal): The Muslim method of slaughter (Halal) is, in many respects, similar to Shechita (160). The animal to be slaughtered must be healthy and conscious at the time of slaughter (Al-Dhabh). Islamic dietary laws prohibit the consumption of alcohol, pork, blood, carrion, and meat which has not been slaughtered according to Islamic rulings. In Halal slaughter stunning is preferably not used, as the animal must be alive at the time of slaying and must die of bleeding rather than as a consequence of stunning (161). However, an increasing majority of the Muslim population are willing to accept stunning as Halal, provided that the stunning method doesn't cause the heart to stop beating, is reversible and otherwise carried out according to the religious standards (162;163). For example, all halal meat produced in New Zealand for export to Asia and the Near East comes from animals killed after electrical sunning (32). Slaughter without stunning is forbidden in New Zealand on grounds of animal welfare (164). As such, a head only stunning method (c.f. Wairoa process) where the current does not reach and stop the heart has been developed that meets Halal standards (165). Similarly, non-penetrating concussion stunning prior to slaughter has received approval from some Muslim authorities (34).

4.8.3.1 Welfare issues

A number of welfare issues during slaughter without stunning have been identified (44) including; pain due to the incision and the rate at which the animals lose consciousness, as this influences the length of time the animal could experience pain and / or distress following the cut (97). Time to collapse can be a useful indicator in the early stages of loss of consciousness. For example, Gregory et al. (166) recorded the interval between the cut and the time the animal was no longer standing on four feet in 174 cattle slaughtered by a skilled Halal slaughterman. Each animal was held individually in the slaughter pen with their head locked in an upright position with a head-yoke and chin-lift. The cut was made upwards across the neck from the animal's right hand side; one cut represented a movement of the blade in one direction. As soon as the required cuts had been made the head and neck were released and the animal was allowed to bleed whilst standing unrestrained in the slaughter pen. If the animal collapsed and subsequently got up again the times to the first collapse and final collapse were recorded separately.

Results show that 25 cattle (14%) collapsed and returned to a four-legged stance before collapsing again, while 14 animals (8%) took 60 seconds or more to achieve their final collapse, one of which had incompletely severed carotid arteries. The average time to final collapse was

19.5 seconds. 90% of the cattle slaughtered collapsed within 34 seconds. There was an association between late collapse following the cut and the presence of large aneurysms in the cardiac ends of the severed carotid arteries. 71%, of cattle that took longer than 75 seconds to collapse, had a cardiac severed artery with an anueurysm that measured at least 3cm in diameter. The recovery of a standing position confirms that the first collapse did not signify total loss of consciousness in all animals. In 14% of the cattle there was a return to sensibility lasting on average 20s. Furthermore, conflicting evidence has been put forward on the time taken for animals to lose consciousness following the severance of the blood vessels in the neck and the extent to which animals experience, or are aware of pain during slaughter (47;55;70;97;105;106;111;167-169). As such it has been concluded that religious slaughter without stunning would compromise animal welfare (170).

4.8.4 Puntila (evernazione)

In many places in the developing world, immobilization of large ruminants (cattle, buffalo, llama) is still carried out through the use of a puntilla (171;172), although it is not condoned by the OIE (29) and is forbidden within the EU (173). Puntila is a traditional slaughter method where the knife is plunged into the back of the neck of the animal to sever the spinal cord through the space between the skull and neck above the backbone (foramen magnum) (96). The procedure aims to induce an immediate collapse of the animal, which can then be stuck and processed in the normal way. However, there is concern that the puntilla is difficult to perform proficiently, which means it is not always a painless way of immobilising cattle or other species. For example, Tidswell et al. (174) showed no apparent change in brain activity (EEG) for 130 seconds after partial section (approximately 80%) of the spinal cord in sheep, suggesting that puntilla can have limited immediate effect on brain function during this time period.

4.8.5 Potassium Chloride (KCl)

Potassium chloride is currently used in the euthanasia of cattle (175-177). It is a preferred injection technique for euthanasia of livestock or wildlife species to reduce the risk of toxicity for predators or scavengers in situations where carcasses may be consumed. The potassium ion is cardio-toxic. A supersaturated solution (1 to 2 mmol / kg of body weight) of potassium chloride injected intravenously or intracardially in an animal under general anesthesia is an acceptable method to produce cardiac arrest and death. Potassium chloride does not have any anaesthetic action and its use should be restricted to anaesthetised animals where it is an efficient agent for causing cardiac arrest. Potassium chloride causes gasping, vocalizations, muscle spasms and convulsive seizures. It is considered unacceptable for euthanasia unless the animal is fully anaesthetized (175-177).

However, a recent DEFRA funded study has examined the use of a CBG / KCl stun / kill regime (10). KCl injected through the hole produced by a penetrating captive bolt stunner was used to promote damage to the structures adjacent to the cortex, mid-brain and to induce cessation of electrical activity (spreading depression) that would prevent recovery of brain activity. Since the spreading depression spreads slowly (2-3 mm per minute) the application of KCl as a stunning method would clearly not meet the legislative criteria for stunning. However, application of KCl stops the action of nerve (and muscle) cells instantly because it abolishes the potassium ion concentration gradient across the cell wall that is essential for cell membrane excitability (intracellular fluid is high in potassium). During the action potential, after the initial influx of sodium, allowing potassium to diffuse through the now open potassium channels into the low-potassium extra-cellular fluid restores the resting membrane potential. If the extra-cellular fluid is high in potassium (because KCl was injected) the recovery phase of the action potential cannot happen therefore, nerve conduction is abolished. Therefore, KCl would produce brain dysfunction if it could be applied directly to the neurons whose function you wanted to discontinue. Further research should be undertaken to confirm that it had also knocked out the brainstem mechanisms responsible for the maintenance of consciousness.

In addition, results suggest it may be possible to reduce the severity of post-stun convulsions [kicking] by using an injection of KCl. A comparison between animals stunned by CBG only (control treatment) and animals stunned by CBG followed by injection of KCl into the bolthole showed a reduction in the intensity of post-stun convulsions when KCl was used (Figure 25). Furthermore, there was no evidence of any signs of recovery following KCl injection, in comparison to animals stunned using CBG only, where signs of recovery were present in some animals after treatment. This suggests that KCl injections may improve operator welfare through the reduction of post-stun convulsions and could improve animal welfare as it may offer a solution to the problem of ineffective captive bolt stunning. However, these results did not reach statistical significance and further trials involving larger numbers of animals under commercial conditions would be required to verify the results of this study before KCl injections could be used routinely. Similarly, the use of chemical agents that result in tissue residues cannot be used for the slaughter of animals intended for human consumption unless they are approved by the Food Standards Agency.

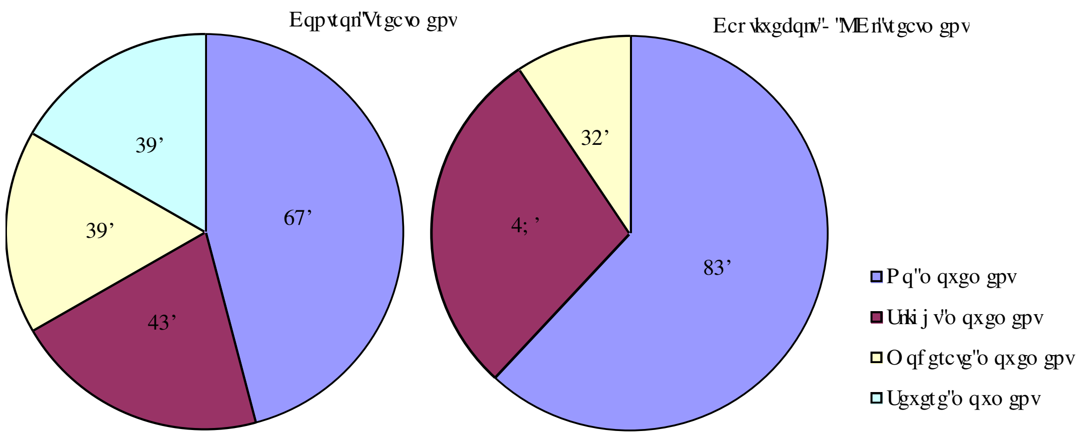


Figure 25 Kicking intensity scores during the stun–shackle period by treatment group (10)

5. RISK REDUCTION MEASURES

5.1 HIERARCHY OF CONTROLS

HSE Guidance on the Management of Health and Safety at Work Regulations (1999) (L21, 178) suggests a hierarchical approach to risk reduction where priority is given to elimination of risk at source (a position supported by the BMPA (179)). Where reasonably practicable the hazard should be eliminated by redesign of the work task, substitution or replacement of tools or components, or through automation of the task (i.e. engineering controls). Where these are not viable, the order in the hierarchy of controls is to minimise risk by designing suitable systems of work, using personal protective equipment (PPE) if appropriate and to provide training (i.e. administrative controls). The following sections discuss a range of possible risk reduction measures spanning the hierarchy of controls, some of which were observed during the site visits, while others are raised as a consequence of observations made during the visits.

5.2 ELIMINATING KICKING DURING SHACKLING AND STICKING

5.2.1 Pithing

Since the BSE (Bovine Spongiform Encephalopathy) outbreak, it is no longer permissible for animals slaughtered for human or animal consumption to be pithed following stunning. However, pithing is considered by the industry to be a valuable tool for maintaining the safety of slaughtermen (114;180) because, the violent limb movement in cattle after captive bolt stunning can be controlled by pithing(1). The reintroduction of pithing in abattoirs would significantly reduce the risk to the operator performing the shackling and sticking operations. However, it is a widely held view that the practice of pithing could spread potentially contaminated central nervous tissue throughout the body during slaughter (26;27;30;32;61;66;72-76;85;181-188). As such, it is unlikely that the EU position regarding the ban on pithing will change. In order to maintain consumer confidence and ensure that GB is able to comply with the BSE measures in force in the other EU Member States, the Restriction on Pithing Regulations 2001 will remain in place for the foreseeable future (189).

5.2.2 Electrical stunning

Electrical stunning has the potential to improve operator safety by eliminating the presence of post-stun convulsions (Section 4.8.2). Under optimum operating conditions this system is satisfactory with no welfare or significant meat quality problems (121;158). The increased reliability of electrical stunning in comparison to CBG provides a definite advantage from a humane slaughter perspective (123). In GB the use of electrical stunning in cattle is limited to date, due to the high investment costs and the belief that the technique will not always be completely effective. However, there are a number of plants in the UK that use electrical stunning. In terms of operator safety during the shackling and sticking process it should be considered good practice.

5.2.3 Electrical immobilisation post stun

Post-stun reflex movements can be eliminated by the application of a low voltage front to rear-end spinal current (121;190;191). Low voltage immobilization current stimulates the (still functioning) nervous system, causing the muscles to contract and the carcass to become rigid. If applied for 45 to 60 seconds (depending on the current), the resulting muscle contraction depletes the energy reserves in the muscles, which become exhausted, and no further movement is possible (95).

The application of electrical stimulation to a carcase was originally introduced in order to speed up the rate of pH fall, hasten rigor onset, and prevent cold shortening. More recently, it has also been applied to carcases to enhance the 'bleeding out' process, enabling more efficient blood collection. (192) The use of low voltage currents to immobilise animals during bleeding is widely practised in Australasia (121), where the immobilising current is applied for occupational health and safety reasons as it reduces the risk of worker injury due to carcases kicking during these operations (95). However, under the The Welfare of Animals at the time of Killing (England) Regulations 2012 (12) electrical immobilisation after reversible stunning and prior to sticking is not acceptable and cannot be carried out within 30 seconds of bleeding, because there is some concern that electro-immobilisation may mask signs of consciousness in those animals that are either insufficiently stunned, or which regain consciousness before bleeding out has continued to the point of insensibility (27;193;194). Therefore, animals have to be stuck immediately after exit from the stunning box, and left to bleed out for a minimum of 30 seconds, before immobilisation using a low-voltage electrical current can occur.

5.2.4 Potassium chloride

Potassium chloride injections may improve operator welfare through the elimination of post-stun convulsions (Section 4.8.5). Further trials involving larger numbers of animals under commercial conditions would be required before KCl could be used routinely. The use of chemical agents that result in tissue residues cannot be used for the slaughter of animals intended for human consumption unless they are approved by the FSA.

5.2.5 Alternative stun box design

A number of different stun box designs are currently available that allow the sticking operation to be conducted within the stun box, eliminating the possibility of the operative being kicked during slaughter (Section 4.2). The viability of sticking within the stunning pen and the impact on hygiene, welfare and throughput would require verification to ensure that the approach is operationally viable in the GB industry.

5.3 ENGINEERING CONTROLS

Where it is not possible to eliminate the operator's exposure to kicking, it is necessary to limit exposure to risk either by limiting time on task, controlling the timing of the task, i.e. only performing the task pre or post clonic phase, or reducing the amount of work that the operator undertakes within the kick envelope. A number of different methods were observed that attempted to modify the shackling task in an attempt to reduce the risk to the operator. The following sections present a series of computer based models that are intended to represent the modifications to the standard slaughter process encountered during the course of this project. These were produced using an ergonomics design and evaluation programme, Jack (version 7.1, Siemens Product Lifecycle Management Software Inc.). Jack can be used to generate scaled human mannequins of known anthropometry. In each of these models the human is representative of a 50th percentile male worker.

5.3.1 Bollards

Health and Safety Authority (Eire, HSA) guidance on the safe handling of livestock at marts and lairages (35) recommends that there should be built in refuge points where a handler or others can shelter or move out of the way if required. Similarly, it should be easy to seal off the facility in the event of cattle escaping. This principle should also be applied to the abattoir side of the operation. There should be a safe escape route available for workers in the sticking area. The use of bollards on the killing floor, as illustrated in Figure 26, provides a safe refuge while shackling and may also act as a means of keeping incorrectly stunned animals from escaping.

Figure 26c&d show the impact of the bollards on the kick envelope and the extent to which the stunned animal is capable of kicking the shackling operator. If the operative is able to shackle from the desired position, the bollards will protect them should the animal start to kick. However, it should be noted that the installation of bollards would not eliminate exposure to kicking at shackling and operatives may still be required to enter the rollout area, as it is difficult to predict how the animal will exit the stun box. It is essential that the area around the bollards remains free of obstructions, as the shackling operative may be required to leave the shackling area should an animal start to kick or return to sensibility.

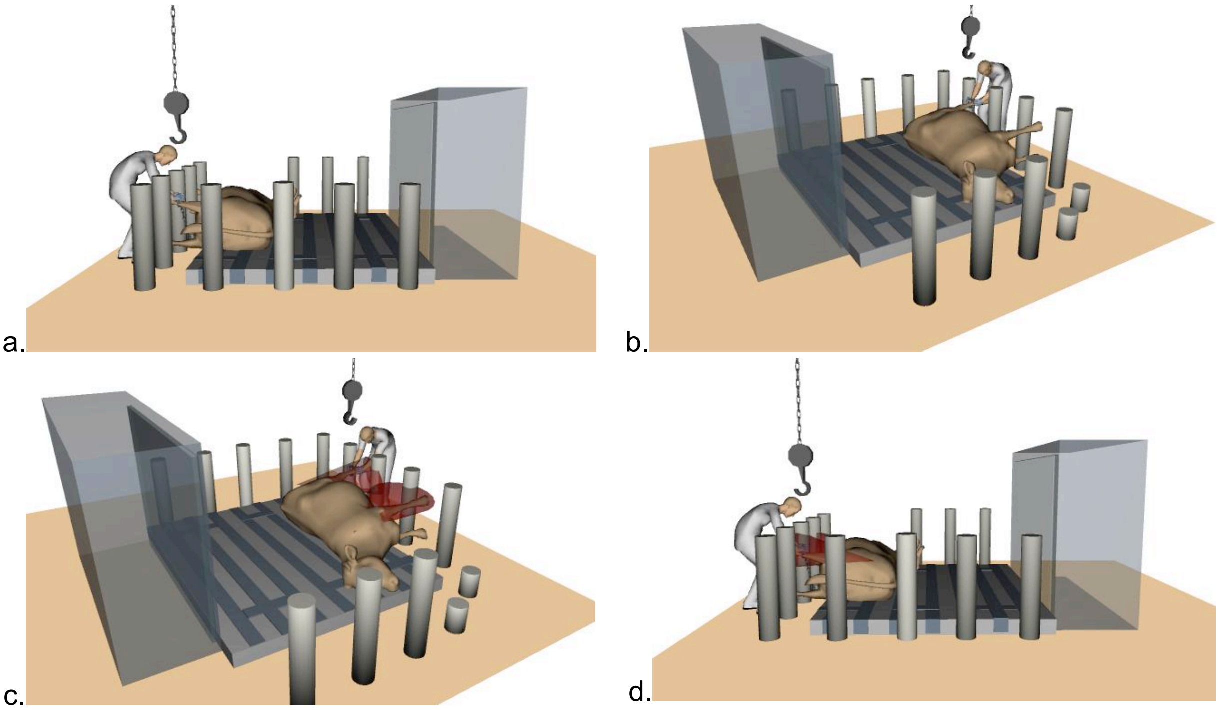


Figure 26 Bollards

5.3.2 Angled stop

Installing an angled stop, so that the beasts legs are presented to the operator, would eliminate the need for the worker to bend down into the kick envelope where risk of kicking is increased. Although, it is difficult to predict how the animal will exit the stun box, the angled stop increases the amount of control the operator has over the animals landing by limiting the distance the beast can roll on exiting the stun box. At the same time, it provides some protection to the lower leg, as the animal will kick against the stop, not the operative's shins. Figure 27a-d show the impact of an angled stop in the middle of the dry landing on the kick envelope and the extent to which the stunned animal is capable of kicking the shackling operator, while Figure 27e-f shows the impact of an angled stop at the end of the dry landing.

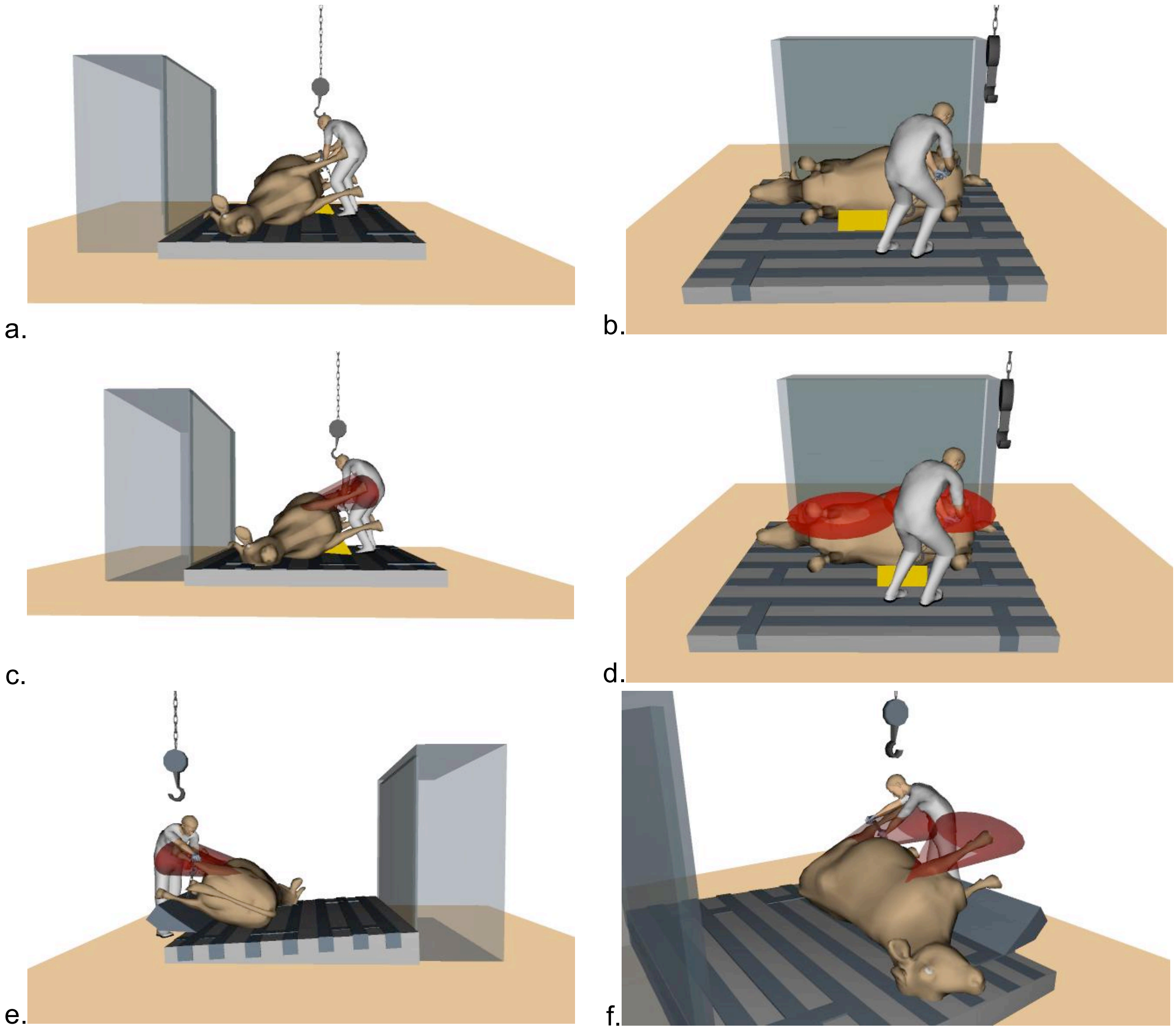
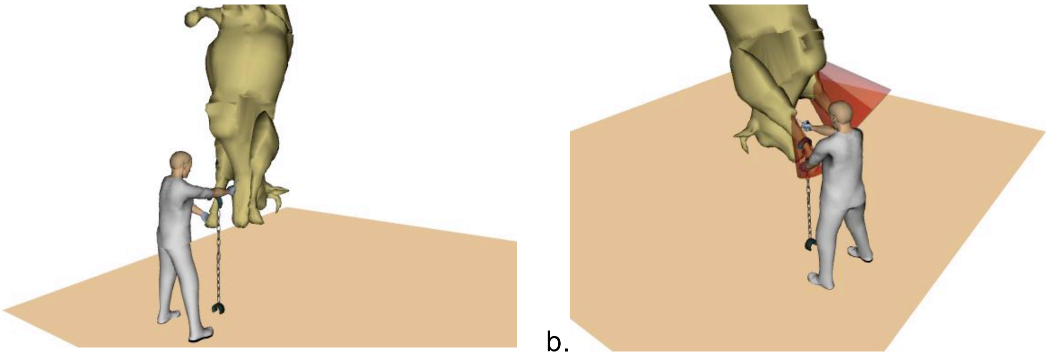


Figure 27 Angled stop mid grill

5.3.3 Chain on foreleg(s) during sticking

When the stunned animal is presented for sticking there should be a safe system of work in place to protect workers, not only from kick injuries, but also from knife cuts and run-through injuries when reflex kicking occurs. Figure 28a&b shows the impact on the kick envelope of chaining the foreleg to the ground and the extent to which the stunned animal is capable of kicking the sticking operator. The thoracic stick requires the operator to work within the kick envelope, increasing the chances of being kicked by an animal exhibiting clonic activity. Shackling of the foreleg would significantly reduce the kick envelope, providing the sticking operative with more space to perform the thoracic stick.



a. b.

Figure 28 Chain of foreleg

5.3.4 Fencing along the bleed rail

The installation of a metal stanchion / fence between the operative and the bleed rail may help to reduce the operator's exposure to kicking by reducing the size of the kick envelope. Figure 29 shows the impact of the metal stanchion on the kick envelope and the extent to which the stunned animal is capable of kicking the sticking operative. As can be seen, the movement of the animal's forelimbs towards the operative would be restricted by the presence of the metal stanchion. Further research to identify the most appropriate design for the metal stanchion would be required in order to ensure its introduction does not interfere with the completion of the task, or introduce any additional risks.

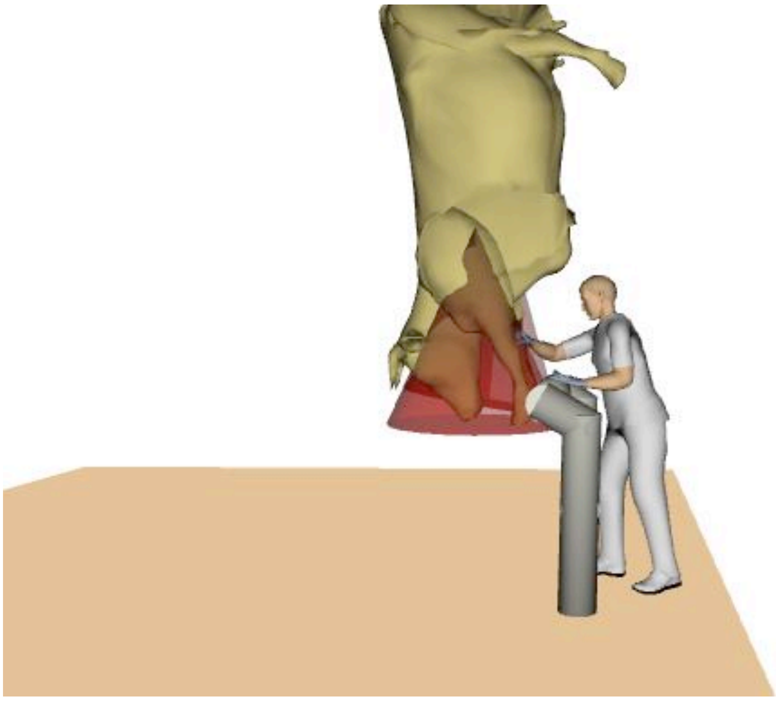


Figure 29 Fence / stanchion between the bleed rail and the operative

5.3.5 Bleed cradle

A modification to existing stun box designs may be possible to enable shackling to be delayed until after the animal is dead. The use of a bleed cradle (Figure 30a) would allow sticking to take place prior to shackling and hoisting the animal, reducing the kick potential and improving operator safety. The use of a bleed cradle raises the working height to a more comfortable level improving posture and reducing fatigue. It also reduces the need of the operator to work within the kick envelope. Figure 30b shows the impact of the bleed cradle on the kick envelope and the extent to which the stunned animal is capable of kicking the shackling operator. However, this would only improve operator safety if there are strict controls in place regarding where the operator is allowed to stand while sticking / shackling. If operators stand in certain locations (Figure 30c) then the risk of kicking injury may actually be increased. Consideration would have to be given to the standard operating procedure and in particular, what to do when the animal exits the stun box in an awkward position (Figure 30d). An additional benefit of the bleed cradle is that it would allow horizontal bleeding. Horizontal bleeding is beneficial as it allows the animal to be bled faster and leads to a higher proportion of blood to be expelled from the animal (195).

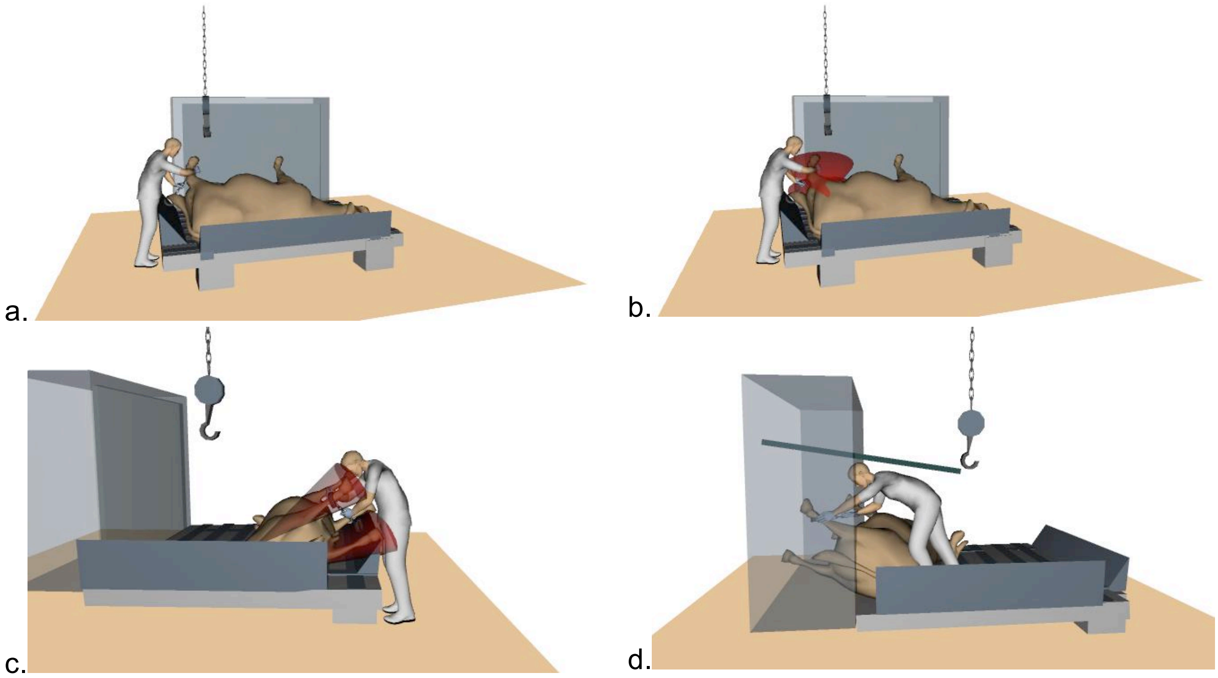
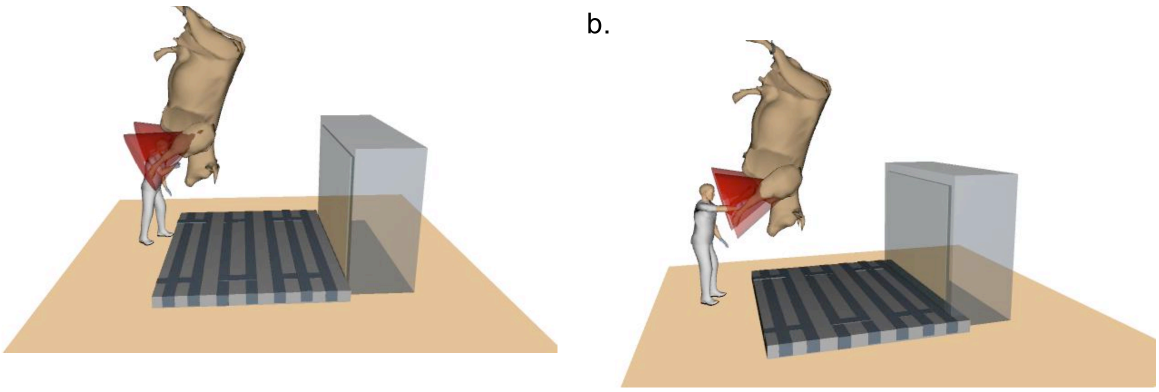


Figure 30 Bleed cradle

5.3.6 Use of a longer knife

Within Great Britain and Europe it is standard practice to use a 6-inch boning knife to slaughter all species (32;180;195). However, the use of a longer knife may increase operator safety. Examination of alternative slaughter methods has highlighted distinct differences between the choice of knife favoured by GB slaughtermen and those outside Europe, where the size of the knife is selected to produce the size of wound required. For example, during Shechita (Jewish slaughter) the knife used to perform the cut must be double the width of the neck (around 16 inches long for cattle). The knife must be long enough so that the end of the knife remains outside the neck. This is essential, as it stops the end of the knife blade digging into the throat causing pain. It is also essential that the wound is held open during the cut. If the wound closes over the knife during the cut, the animal will struggle (34;49;51;52;55;133;159;161;196-198). The use of a knife of this length during slaughter with prior stunning may serve to increase the distance of the operative from the animal when sticking, which in turn, may reduce the amount of work that the operator undertakes within the kick envelope (i.e. outside the reach of the forelimbs). However, this would also require the development of a system to maintain the stability of the animal, which is usually hanging from the hoist under its own weight. Without such a system the sticking task may be made more difficult, as it may make it more difficult to accurately stick the animal. There may also be a delay in severing the required arteries, increasing the likelihood of return to sensibility and post-stun kicking.



a. b.

Figure 31 Long reach knife

5.4 ADMINISTRATIVE CONTROLS

5.4.1 Safe system of work

If risk is unavoidable then a safe system of work should be in place, which ensures that all reasonably practicable measures have been taken to reduce risk. As such, the results of a detailed risk assessment should be used to help identify the necessary risk reduction measures for inclusion in a safe system of work. To this end, Article 6 of EU Regulations 1099/2009 requires that business operators plan all killing operations in advance and carry them out in accordance with Standard Operating Procedures (28).

The following sections cover a number of specific risks that could be reduced, through the use of administrative controls and which could be incorporated into the organisations safe system of work.

5.4.2 Number of people in shackling / sticking area

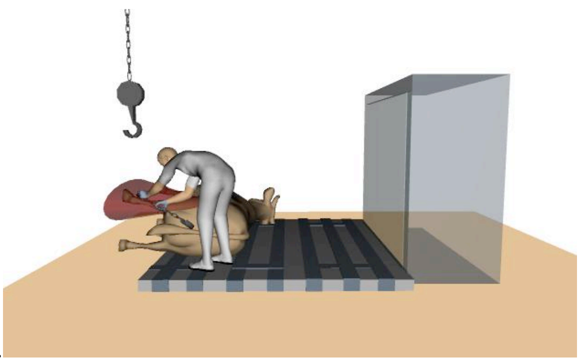
The number of people present in the shackling and sticking area may contribute to the risk of injury. At some abattoirs visited as part of this research, there was one operative per task (stunning, shackling and sticking), while at others there was one operative to perform all three tasks. This led to some fundamental differences in the management / control of the killing floor. At one site, there was a ban on anyone other than the operative performing the stunning, shackling and sticking from entering the killing floor. The FSA officer was able to check the tag on the animals as they entered the stun box and again as they left the bleed rail. This was possible as the tagged ear was left attached to the carcass during the head dressing process, so that the animal was still identifiable as it progressed along the rail. This was in contrast to other sites where access to the shackling and sticking areas was less controlled. For example, at one site nine operatives were observed within the shackling and sticking area. Although this was on returning from a shutdown in production, the non-slaughter operatives remained in the shackling and sticking area for a significant amount of time after production had restarted. This could have a considerable impact on the safety of the operatives; distracting the shackling and sticking operative can increase the likelihood of them being injured, should the animal kick. The operator performing the shackling / sticking tasks may not be aware of the movements of other workers around them. This is evidenced by a number of incidents reported under RIDDOR that were knife related and a consequence of the operator not being aware of the movements of others on the line. Ensuring that as few employees as possible are located in the shackling and sticking area will reduce the possibility of workers being kicked by the animal and reduce the likelihood of knife injuries resulting from proximity of workers.

5.4.3 CBG use and maintenance

It is impossible to predict which animal will kick, however there are a number of things that can be done to reduce the chance of the animal kicking and the associated risks. Selecting the most efficient captive bolt gun, improving shooting accuracy and efficiency of stun should reduce post-stun convulsions. High bolt velocity causes a concussion that induces instantaneous insensibility (67;68;78). Bolt velocity can be affected by a number of factors, including, gun type and conditioning and choice of cartridge. Reasons for failure to stun properly in cattle abattoirs were identified to be related mainly to the stun weapons used (24). It is important to ensure that all operators involved with stunning and slaughter are competent and properly trained with regard to mechanical stunning methods and the use of CBG in particular (27). They should be aware of the appropriate use of stunning equipment, the correct presentation of the animal for stunning, have the skill to ensure that the animal is presented so that the equipment can be applied and operated easily, accurately and for the appropriate time, be aware of the signs of an effective stun and recovery, and if the animal shows signs of recovery have the knowledge and ability to take the necessary action to ensure that the animal is re-stunned or, if appropriate, killed without delay. In addition, each abattoir should have a system of verified maintenance in which, CBG must be cleaned and serviced, following the manufacturer's recommendations, to maintain maximum hitting power and to prevent misfiring or partial firing (64). Article 9 of the Welfare of Animals at the time of Killing (England) Regulations 2012 (12) sets out the legal requirement for business operators to draw up a record of maintenance and to keep those records for at least one year; making them available to the Competent Authority on request.

5.4.4 Positioning of the operative

The positioning of the operator is a central facet of the risks associated with the shackling and sticking task. The shackling and sticking tasks require the operative to work predominantly within the kick envelope. This represents a high level of risk to the operator should the animal kick during slaughter. In terms of risk reduction, the task should be designed to minimise the time spent within this zone. Where possible, shackling should take place while the operator is standing on the dorsal (back) side and at the caudal (rear) end of the animal, away from the animal's legs, and not between the animal's head and a fixed object. This is illustrated in Figure 32, which shows how the operative can be removed from the kick envelope by being positioned at the tail of the animal while shackling.

a. 

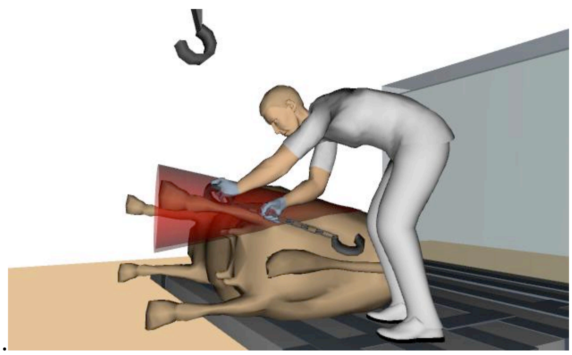
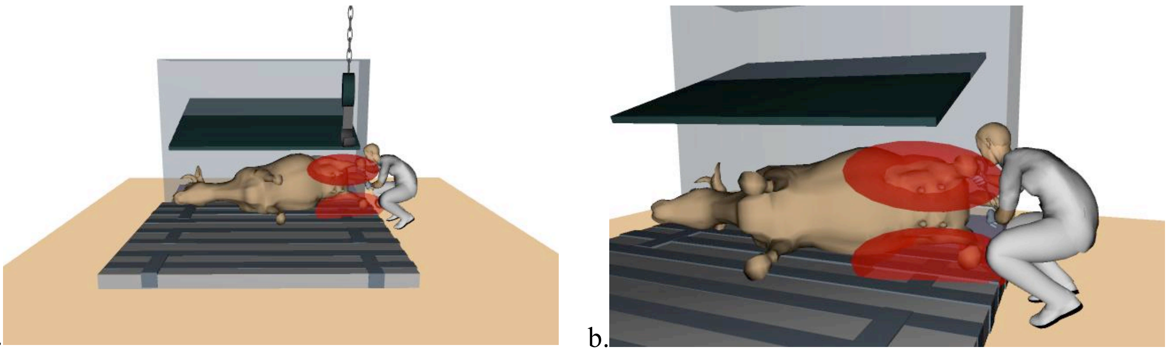
b. 

Figure 32 Positioning of the operative

However, from discussion with shackling and sticking operatives and health and safety managers during the site visits it is evident that the preferred position of the shackling operative is to stand between the front and rear legs of the animal. This places them directly in the kick envelope. Furthermore, the majority of abattoirs had no clear procedure regarding the position that the shackler adopts when attaching the shackle. The main reason given for this was that the position of the operator is dependent on the position at which the animal exits the stun box, which can be unpredictable. The difficulty of the shackling task in particular, can be exacerbated when the animal exits the stun box in an awkward position. Under these circumstances, standing at the rear of the animal may not be possible and would mean that the operative would have to adopt an awkward posture to attach the shackle. This may increase the risk of injury, as the operative may have to work within the kick envelope while off balance, or while less aware of the positioning of the animal's legs (Figure 33a&b). Further work is recommended to investigate the positioning of the operator during the shackling and sticking tasks. This work could take place within the context of work to refine the kick envelope, as the positioning of the operator and the extent of the kick envelope combine to define the level of risk to which shackling and sticking operatives are exposed.



a. b.

Figure 33 Awkward positioning of the animal

5.5 PERSONAL PROTECTIVE EQUIPMENT (PPE)

Shackling, sticking and allied processes produce hazards which are determined mainly by process conditions and dealing with the unpredictable nature of a stunned animal. Often, the nature and severity of post-stun convulsions determine the type and levels of risk associated with the slaughter process. Only when these risks have been determined and, where appropriate, other control measures used to reduce the level of risk associated with a task, can consideration be given to further reducing the risks by use of personal protective equipment (PPE). The provision of PPE is covered by the Personal Protective Equipment at Work Regulations 1992 (as amended) (199). Within these Regulations PPE is defined as 'all equipment (including clothing affording protection against the weather) which is intended to be worn or held by a person at work and which protects him against one or more risks to his health or safety' (200), e.g. safety helmets, gloves, eye protection, high-visibility clothing, safety footwear and safety harnesses (201).

Personal protective equipment should be supplied and used at work wherever there are risks to health and safety that cannot be adequately controlled in other ways. However, it may not be possible to use measures other than PPE to control risks and in these cases PPE, normally the last line of defence, becomes the only line of defence available to adequately protect workers. Therefore, it is of vital importance that suitable PPE is chosen for the job and that the performance standard required from PPE is determined directly by the nature and level of risk involved in performing the task. An important consideration is to determine those parts of the body at risk. The extent of risk will be influenced by the frequency and duration of the exposure. Effective protection can only be provided by PPE when it is suitable for the task in hand, is adequately maintained and is used correctly by a user who has been trained to use it.

When the PPE is in place the duty holder should:

- Train and instruct people in the correct use of PPE, making sure they are aware of why it is needed, when it is to be used, repaired or replaced and its limitations. Often PPE is the last resort, after other methods of protection have been considered, it is important that users wear it whenever they are exposed to the risk. Regular checks should be made to ensure that PPE is being used properly and any reasons why it is not should be fully investigated.

- Make sure equipment is: well looked after and properly stored when it is not being used, for example in a dry, clean cupboard, or in the case of smaller items, such as eye protection, in a box or case; kept clean and in good repair - follow the manufacturer's maintenance schedule (including recommended replacement periods). The trained wearer can carry out simple maintenance, but specialists should perform more intricate repairs. Make sure suitable replacement PPE is always readily available.

5.5.1 Current PPE

BMPA guidance (GN 1-37, (179)) describes the types of PPE recommended for operatives performing the stunning and sticking tasks. The main risks identified for stunning and sticking operatives include:

- Kicks and attacks (animal related), cuts, falling objects, slips, zoonoses, and particulate sprays.

To counter these risks it is recommended that stunning and sticking operatives wear:

- Steel toe capped waterproof [Wellington] boots with a deep tread sole pattern suitable for gross debris; overalls (laundered daily), hearing protection.

In addition, those performing the sticking task should also wear cut resistant gloves and waterproof gloves / gauntlets, eye protection, hardhat and chain mail gloves, arm guards, or sleeves. However, the main piece of equipment for meat processors is a protective apron, made from plate link or preferably chain mail that is designed to protect the chest and abdomen from knife related injuries, particularly when the knifepoint is pulled towards the body e.g. during de-boning. Aprons should be sufficiently long to provide adequate protection depending on the nature of the work e.g. usually covering the body area from mid breast bone to mid thigh. The weight of the apron should be borne by the wearer's shoulders and not the neck, and be adjustable so it sits neatly against the body without sagging. For certain operations, a tunic covering the shoulders and upper torso may be required e.g. reaching upwards to work on hanging meat in pre trimming or using pullers/liberators. In terms of kick protection this would afford the operator limited protection from injury.

The main areas at risk during the sticking task are the torso (thorax / chest) and the face and head. Additional protection that covers these areas may reduce the risk of kick injury. It would be beneficial to operatives performing the shackling and sticking operations for industry to work with PPE manufacturers to develop specific equipment to reduce the impact of kick injury. An alternative approach would be to look at tasks where the risks of injury are similar and where

PPE already exists, such as equestrian or rodeo riding, ice hockey, lacrosse or American football. Some anecdotal feedback during the course of this research suggests that a small number of slaughtermen already wear facemasks or protective helmets, although these were not observed during the site visits. The following sections provide a brief overview of some of the existing equipment that may be adopted / adapted for use in the abattoir environment. None of these items have been trialled or tested under occupational settings and as such there may be limitations to using these items as PPE.   Additional research would be required to examine the suitability and efficacy of any additional PPE prior to implementation.

5.5.2 Face masks

The use of facemasks as worn by bullfighters, ice hockey players, etc could help reduce the impact / force of a blow should an operative be kicked in face or head while shackling or sticking. Injuries cannot be entirely prevented by wearing facemasks, but the severity of any impact and prospective injury severity could be reduced. Figure 34a shows a bull riding helmet that consists of a vinyl nitrile shell and a synthetic foam liner, which are designed to be durable and to absorb the impact of blows to the head. The shape of the helmet is designed to optimise impact deflections. Figure 34b shows an alternative protective facemask for bull riding made from padded leather. A four bar metal face guard protects the chin, cheekbone, temple, and forehead areas. There are a number of other sports that have similar protective facemasks. Figure 34c-f illustrates a number of possible solutions that may serve to reduce the impact of kicks received during the slaughter process.

Further research would be required to examine the suitability of these items within the abattoir. In particular, whether facemasks can prevent or adequately control the risks during slaughter without increasing the overall level of risk. For example, facemasks may restrict the wearer to some extent by limiting movement and / or visibility (201), which under the constraints of abattoir work may actually increase the risk of being kicked. Similarly, if the operative were to be kicked whilst wearing such a helmet the force of a kick could cause an injury to the neck area due to the weight of the helmet / head and the possible rotational force that could be applied by the animal's kick (a neck brace / support could be worn to reduce the effect, although these may further restrict neck movement). In addition, wearing a facemask may become hot and uncomfortable to wear, particularly during the summer months, increasing the physical demands placed on the operative.

a.

b.

Figure 34 Facemasks: a. Rodeo, b. Rodeo, c. Field hockey, d. Lacrosse, e. Ice hockey, f. American football

5.5.3 Chest / body protectors

The use of protective vests as worn by many rough stock [rodeo] contestants (particularly in the bull riding event) could help reduce the impact / force of a blow should an operative be kicked in the torso while shackling or sticking. Injuries cannot be entirely prevented by wearing a body protector, but the severity of any impact on the body and prospective injury severity could be reduced. Rodeo vests are made of high-density foam or ballistic materials and are similar to bulletproof vests worn by police. Use of protective vests in rodeo has significantly reduced the number and severity of injuries to contestants (202-205). Similarly, the British Equestrian Trade Association (BETA, www.beta-uk.org) recommends that chest / body protectors are used when riding and handling horses. Equestrian body protectors are foam filled vests, which are worn over the top of clothes and are designed to give protection to the back and chest area of the rider should they fall or be kicked (Figure 35). Within the abattoir setting they could easily be worn over the top of the workers' white overalls and under the stab apron, or as an integrated garment. The use of chest protectors may also benefit those operatives working in the lairage, as a significant number of injuries are reported each year that relate to cattle handling (15;35;206).

a. b.

Figure 35 Body / chest protectors (a. rodeo, b. equestrian)

The design of the body protector should conform to the current safety standards BS EN 13158: 2009 (207) and BETA 2009[7]. The BETA Standard (209) sets criteria for shock-absorption, controls the area of the body that must be covered and ensures there are minimal gaps between the protective foam panels. It encompasses three levels, each designed for different activities:

- **Level 1:** Provides the lowest level of protection that is only considered appropriate for licensed jockeys while racing;

- **Level 2:** Offers a lower than normal level of protection so is considered suitable for low risk situations - not including jumping, riding on the roads, riding young or excitable horses or riding while inexperienced;

- **Level 3:** Is considered appropriate for general riding, competitions including eventing and working with horses. In order to perform the protective function, the materials from which the garments are constructed should compress more easily than the underlying tissues covered by the body protector (i.e. the torso, ribcage and part of the abdomen). Because these tissues are relatively weak, this means they cannot absorb much energy. Thus Level 3 body protectors can be expected to prevent minor bruising that would produce stiffness and pain, reduce soft tissue injuries and prevent a limited number of rib fractures.

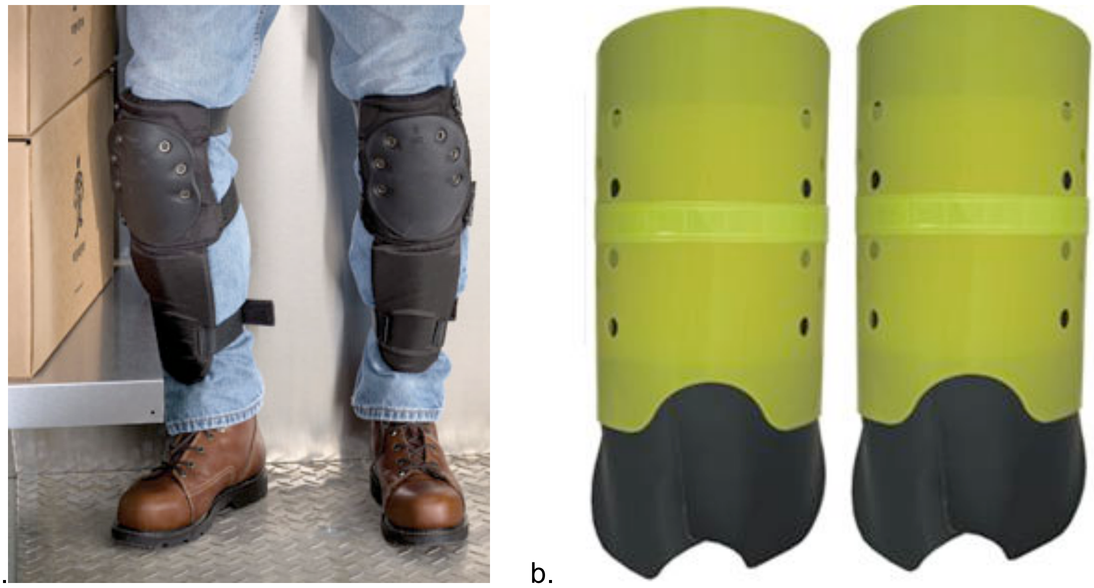
For a body protector to offer maximum protection it must be adjusted to fit securely and reasonably tightly around the body. Most body protectors are made from heat sensitive PVC nitrile foam, which means that with use they will soften and mould to the wearer's body. As such, each individual should have his or her own body protector so that it can mould itself to the user's body shape increasing comfort and fit. Body protectors should be replaced at least every 3-4 years as the foam padding may start to degrade. In addition, any body protector that is

[7] ASTM F1937 - 04(2010) Standard Specification for Body Protectors Used in Horse Sports and Horseback Riding, for vests produced in the USA (208).

dented after an incident should be replaced immediately as the impact absorption properties are likely to be diminished. Further research would be required to establish the efficacy of such protection within an abattoir setting. Similarly, ergonomic considerations such as usability, compatibility with existing PPE and thermal comfort will influence the effectiveness of chest protectors as PPE in the abattoir environment. Within the abattoir setting the use of body protectors should not be relied upon as a control measure, but as a means of reducing the impact should other controls fail.

5.5.4 Shin Guards

The use of shin guards could be applied to the abattoir environment to provide lower leg protection. They may reduce the impact / force of a blow should an operative be kicked while shackling or sticking. Typically, shin guards have a hard shell outer layer to the front to protect against impact, but have little or no protection on the calf. Shin guards have been widely applied in a variety of industrial settings, particularly in construction, and could easily be applied to the meat industry (where appropriate). Further testing would be required in order to find out the extent to which wearing shin guards would reduce the severity of impact. Figure 36a shows a set of combined knee and shin guards for industrial use. They are constructed from nylon and filled with high-density polyethylene foam pads manufactured to form to the lower leg. Adjustable straps with buckle closure provide a comfortable, secure fit.



a. b.

Figure 36 Industrial shin guards

5.5.5 Padded shorts

The use of padded shorts as worn by bullfighters, ice hockey players, etc. could help reduce the impact / force of a blow should an operative be kicked in the upper leg while shackling or sticking. Injuries cannot be entirely prevented by wearing padded shorts, but the severity of any impact and prospective injury severity could be reduced. Figure 37a shows a pair of padded bull riding shorts made from heavyweight spandex with a series of high-density polyethylene (foam rubber) inserts to protect the thighs, hips, and tail bone. Similarly, Figure 37b shows a pair of padded shorts designed for ice hockey. The outer layer is typically constructed from a durable nylon material that can be waterproofed (providing the operator with additional protection), while the inner layer comprises a series of plate inserts that protect the thigh, pelvic, hip and tailbone.

a. 

b. 

Figure 37 Padded shorts for a. bull riding and b. ice hockey

6. IMPLICATIONS

6.1 CONCLUSIONS

It is impossible to stop animals from kicking during slaughter with a stun / kill protocol based on captive bolt stunning. Approximately 30% of cattle observed in this study kicked during the shackling task, while approximately 10 % of cattle observed kicked during the sticking task. These figures are consistent with previous studies (81;180). Furthermore, it is difficult to predict which animal will have post-stun convulsions and how strong those convulsions will be. This uncertainty makes it difficult to directly control the likelihood and severity of kicking during the shackling and sticking tasks. As such the aim becomes to eliminate the hazard or reduce the risk to the operator by redesigning the work task. Beyond this it is a matter of demonstrating that all that is reasonably practicable has been done to protect the safety of staff performing the stunning, shackling and sticking tasks and making continual incremental improvements in the process, with the aim of reducing the level of risk to the operator. This report has identified several possible solutions that may be taken forward by industry that could help to improve the safety of operators performing the shackling and sticking tasks.

With respect to the aims and objectives of this study the following conclusions can be drawn:

- The slaughter operations in abattoirs vary considerably due to different technical design, different stun systems and different killing rates.

- The main factor that influences the amount of kicking is the accuracy of the stun, while the captive bolt gun used, strength and calibre of cartridge, and the positioning of the stun influence stun efficacy.

- The shackling and sticking tasks typically place the operative at risk of being kicked during the slaughter task, as the operative is required to work predominantly within the kick envelope, i.e. within the functional reach of the animal's limbs.

- Approximately 30% of cattle observed in this study kicked during the shackling task, while approximately 10 % of cattle kicked during the sticking task.

- The number of people present in the shackling and sticking area may contribute to the risk of injury.

- Electrical stunning equipment can eliminate kicking during the shackling and sticking process. Under optimum operating conditions, it meets reliability, animal welfare and meat quality standards. However, the use of electrical stunning is presently little used and is relatively expensive in comparison to traditional / conventional equipment and would have significant cost implications for industry.

- Alternative stun box designs that allow the sticking operation to be conducted within the stun box, have the potential to improve operator safety within the slaughter industry, as they could eliminate kicking during the shackling and sticking process.

- With further research potassium chloride (chemical pithing) has the potential to be used as a means of reducing the level of post-stun convulsions.

- Electrical immobilisation can eliminate post-stun convulsions. However, under the Welfare of Animals at the time of Killing (England) Regulations 2012, electrical immobilisation cannot be carried out within 30 seconds of bleeding, as it may mask signs of inaccurate stun.

- A number of engineering controls (e.g. bollards around the stun box, bleed cradles, chaining the forelegs, etc) have the potential for reducing the risk of kick injury while shackling and sticking.

- A number of administrative controls (e.g. captive bolt gun maintenance, positioning of the operative, improved training, etc), constituting a safe system of work, have the potential to reduce the risk of kick injury while shackling and sticking.

- With further research the use of Personal Protective Equipment (PPE) has the potential to reduce the impact of kick injury.

6.2 POINTS FOR FURTHER CONSIDERATION BY THE INDUSTRY

The following points for further consideration are raised as they may protect, improve or maintain the health and safety of slaughtermen during the shackling and sticking process.

6.2.1 With respect to the task

Standard operating procedure: A number of sites visited during the course of this investigation did not have a documented operating procedure for shackling, sticking and allied activities. It is good practice to document and display standard operating procedures (SOP), as this would contribute to the development of a safe system of work.

Access to the stun box, restraining crush and adjacent area should be restricted to appropriately trained and protected workers: Fundamental differences exist between abattoirs in the management of the killing floor. Restricting anyone other than the operatives performing the stunning, shackling and sticking from entering the killing floor may reduce the possibility of a distracted worker being kicked by the animal, or the risk of a non-slaughter operative being injured.

Improve communication between stakeholders: Effective communication and sharing of information within the industry may help to reduce the risk of kick injury, as key industry stakeholders share information on good practice and successful risk reduction.

Electrical stunning: Further research should be conducted to examine the feasibility of applying an electrical stun / kill slaughter protocol within the GB slaughter industry.

Potassium Chloride: Research is needed to examine the feasibility of using potassium chloride injections to improve operator safety. Further trials involving larger numbers of animals under commercial conditions are recommended in order to establish whether a safe, reliable and humane slaughter protocol can be developed. The use of chemical agents that result in tissue residues cannot be used for the slaughter of animals intended for human consumption unless they are approved by the Food Standards Agency.

6.2.2 With respect to the individual

Selection, training, on-going supervision and assessment of stunning operators: Captive bolt stunning has the disadvantage that there is no automated method for practical use available today and successful stun depends on the education and skill of the person who performs the stunning (89). Therefore, employees need to have good training on how the selected stun method is used. This should include where the stun should be applied, the signs of an effective stun and what to do if the animal shows signs of return to sensibility. It is good practice for other employees working on the killing floor to have had similar training as the operator performing the stunning and to have ready access to a backup stunning device, should it be required.

Operator fatigue: Fatigue is a major cause of missed CBG shots (49) and can increase the chance of post-stun convulsion (64;81). The prevention of overloading / fatigue may require employment of two CBG operators or frequent rotation of cross-trained operators. Assessment of stunning efficiency at the end of the shift would help to identify if fatigue is a significant issue (49).

6.2.3 With respect to the environment / equipment

Alternative stun box design: Industry should look at alternative stun box designs, particularly those that allow sticking of the animal, in situ, prior to shackling and hoisting onto the bleed / dressing rail. From a worker safety point of view, sticking should be performed whilst the animal is still in the tonic phase (27). This makes the cut easier to carry out and helps protect the slaughter personnel from kick or knife injury (95). Therefore, alternative stun box designs have the greatest potential for improving operator welfare within the slaughter industry. One potential drawback to alternative stun box designs is that they may have impact on the number of animals that can be slaughtered. The changes to the slaughter process may increase total task time as an animal would need to be completely bled, before the next animal can enter the box (any changes should not affect stun-to-stick times on animal welfare grounds). However, operator safety should be considered more important than production, particularly as many of the sites visited did not operate at full capacity and cattle could be slaughtered over a greater part of the workday. This may provide an additional benefit, in that a greater balance may be struck between the work pace demands of the task and operator fatigue.

Alternative killing floor design: Section 5.3 presents a number of possible design options that modify the shackling task in an attempt to reduce the risk to the operator by limiting the amount of work that the operator undertakes within the kick envelope. Industry should explore the feasibility of these suggestions; conducting further work to examine the efficacy of these solutions in terms of risk reduction.

Operational care and maintenance of stunning equipment: One of the most common causes of low efficacy scores for use of captive-bolt stunning equipment is the use of unclean or un-serviced guns, with worn out parts, due to poor maintenance. As such, each abattoir should have a system of verified maintenance in which, the CBG must be cleaned and serviced, following the manufacturer's recommendations, to maintain maximum hitting power and to prevent misfiring or partial firing (*this has become a legal requirement under the Welfare of Animals at the time of Killing Regulations 2012*).

Personal protective equipment (PPE): Section 5.5 presents a number of existing items of PPE and sports equipment that could be adapted for use in the abattoir environment. However, very few of these items have been trialled or tested under occupational settings and, as such, there may be limitations to using these items as PPE. It is recommended that additional research is conducted to establish the suitability and efficacy of these items as PPE in the abattoir setting. If these items are found to be unsuitable, it would be beneficial to operatives performing the shackling and sticking operations for industry to work with PPE manufacturers to develop specific equipment to reduce the impact of kick injury, where possible.

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8. GLOSSARY

Bovine Spongiform Encephalopathy – BSE, a fatal, degenerative disease of the central nervous system that occurs in cattle. It is one of a number of similar diseases known as transmissible spongiform encephalopathies (TSE),

British Meat Processors Association (BMPA) – UK trade association for the meat and meat product industry. Formed in 2003 from the merger of two associations, the British Meat Federation (BMF) and the British Meat Manufacturers' Association (BMMA).

CBG – Captive bolt gun

Death - Irreversible loss of brain activity as demonstrated by loss of brain stem reflexes.

Exsanguination – Fatal blood loss (hypovolemia) sufficient to cause death

Halal slaughter – Slaughter of a religiously acceptable species by a trained Muslim slaughterman, with or without prior stunning, by cutting the neck in order to sever the jugular veins and carotid arteries, oesophagus and trachea, without severing the spinal cord, while the animal is alive.

Kosher slaughter – Slaughter of a religiously acceptable species, by trained and accredited Jewish slaughterman, by cutting the neck in order to sever the jugular veins and carotid arteries, oesophagus and trachea of a conscious animal, without severing the spinal cord.

Lairage – pens, yards and other holding areas used for accommodating animals in order to give them necessary attention (including water, fodder, rest) before they are moved on, used for specific purposes, or slaughtered.

OV – Official Veterinarian

PPE – Personal protective equipment

Pithing – The insertion of a flexible wire or polypropylene rod, through a hole in the head made by a captive bolt stunner to kill the animal by lacerating the central nervous tissue, physically destroying the brain stem and surrounding parts of the central nervous system.

Slaughter – Any procedure that causes the death of an animal by bleeding.

Slaughterhouse – Premises, including facilities for moving or lairaging animals, used for the slaughter of animals for human consumption or animal feeding and approved by the National Veterinary Services or other competent authority.

Stunning – Any mechanical, electrical, chemical or other procedure which causes immediate loss of consciousness which lasts until either the animal is killed or it recovers.

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Reducing the risk of kick injury during the shackling and sticking of cattle in abattoirs

The slaughter operations in abattoirs vary considerably due to different technical design, different stun systems and different killing rates. The shackling and sticking tasks place the operative at a high risk of being kicked during the slaughter task, as the operative is required to work predominantly within the kick envelope, ie within the functional reach of the animal's limbs. It is impossible to stop animals from kicking during slaughter with a stun/kill protocol based on captive bolt stunning. Furthermore, it is difficult to predict which animal will have post stun convulsions and how strong those convulsions will be. This uncertainty makes it difficult to directly control the risk of kicking during the shackling and sticking tasks.

The purpose of this report is to investigate the shackling and sticking tasks, in order to find ways to eliminate or reduce the risk to the operator by redesigning the work task. Beyond this it is a matter of demonstrating that all that is reasonably practicable has been done to protect the welfare of staff performing the stunning, shackling and sticking tasks and making continual incremental improvements in the process, with the aim of reducing the level of risk to the operator.

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