

Musculoskeletal Disorders in Meat Processing:

A review of the literature for the New Zealand meat processing industry

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Introduction

This review of the peer-reviewed research literature was compiled as an output of the 2004-2006 COHFE project *Addressing Work-related Musculoskeletal Disorders in Meat and Seafood Processing*, conducted in collaboration with Massey University and funded jointly by the Health Research Council New Zealand, ACC and OSH.

The aims of this literature review on musculoskeletal disorders (MSD) in meat processing were to establish the current state of knowledge regarding risk factors, interventions, and barriers to their implementation. It is intended to give people working in the New Zealand meat industry insights into the strength of evidence behind the different current ideas on addressing MSD.

There are few conclusive scientific studies whose findings can be applied directly and confidently in industry. For example, the review reveals that while a lot of work has been done on biomechanical risk factors affecting the upper limbs, most of this has been done in laboratories - rather than in actual plants with all the other operational considerations. The results of these laboratory studies can be very conclusive therefore, but caution is needed when attempting to transfer the findings to the dynamic and complex conditions existing in a working plant.

Significant gaps in our knowledge are also highlighted. The review shows that although many authors have identified the suspected effectiveness of work organisation in moderating MSD risk factors, this strong call is not well supported by evidence; virtually no research has actually been done on the effectiveness of organisational level interventions that relates directly to the New Zealand meat industry.

Method

The review material was drawn from searches of the following sources:

- Ergonomics Abstracts (database)
- Web of Science (database)
- Meat Industry Research Institute of New Zealand (MIRINZ) library catalogue (AgResearch, Ruakura Campus, Hamilton)
- ACC library catalogue (New Zealand)
- OSH library catalogue (Department of Labour, New Zealand)
- South Pacific Ergonomics Ltd (Auckland, New Zealand) archives.

Criteria used to determine inclusion of literature in this review are specified below:

- Content that was directly relevant to MSD risk factors in the red meat and seafood processing industry. Generic studies on MSD were excluded unless they were highly significant pieces of work.
- Peer reviewed material (journal papers, book chapters, conference papers, and reports from major research centres) were included in preference to: trade magazine articles, newspaper items, student assignments or personal communications on the same topics.
- Overseas material was restricted to publications since 1985. Pertinent New Zealand and Australian references are included, irrespective of date.

The initial literature search was conducted in August 2004 with a follow-up search in April-September 2006. Peer review of the draft was conducted by David Riley (Ergonomics Team Leader, Health and Safety Laboratory, UK).

The following factors limited the review:

- Differences in definitions and classifications between countries.
- Guides on MSD prevention (e.g. OSH, 1997) and major industry reports usually lack referencing to their research evidence base, and so the strength of the scientific support for the recommendations made cannot be judged.
- The scientific papers commonly stopped short of discussing in full the implications of the findings for industry.
- Inconsistency and gaps in the literature. For example, the absence of a coherent set of robust and convincing evaluation studies with repeatable methodologies that demonstrate the effectiveness of the interventions promoted – in particular those relating to work organisation factors.
- Some highly relevant industry research carried out within individual companies remains unpublished for reasons of maintaining competitive advantage.

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1. *MSD in meat processing*

1.1 *Introduction*

Work-related musculoskeletal disorders (MSD) describe a wide range of inflammatory and degenerative disorders and diseases resulting in pain and functional impairment (Buckle & Devereux, 2002). Factors outside the workplace may influence their onset or exacerbate conditions, but the relationship between the performance of work and MSD is now well evidenced (Buckle & Devereux, 2002).

The Occupational Safety and Health Administration (OSHA) Ergonomics Program (1999) states that there is a positive relationship between work-related musculoskeletal disorders and workplace risk factors in the USA, evidenced by:

- More than 2,000 articles on work-related MSD and workplace risk factors
- A 1998 study by the National Research Council/National Academy of Sciences on work-related MSD
- A critical review by NIOSH of more than 600 epidemiological studies (NIOSH, 1997)

The problem of MSD in the meat industry was highlighted in the USA during the 1980s (Conroy, 1989) when a reported general increase in output within the US meat industry was followed by a series of legal actions by OSHA. Two prominent U.S. companies were fined in 1987 and 1988 for a series of violations related to record keeping and high incidence rates. Both reached settlement agreements with OSHA which reduced the fine by agreeing to instigate long term ergonomics programmes. The fine for one company was still US\$4.33 million. The US meat industry has, however, remained a recognised poor performer (NIOSH, 1994).

Much of the research literature comes from the USA and Northern Europe including Britain, but there appear to be enough similarities in work methods for these studies to have relevance in New Zealand. There is also broad agreement within the literature on what the major risk factors for MSD are, but direct comparisons on the extent and cost of MSD nationally in the different countries are problematic due to differences in reporting and recording methods.

Comparative descriptions of the meat industries in the various countries would also assist interpretation but are generally not included in the studies reported in this literature. Nossent et al. (1995) however as an exception do provide some useful background data on the European scene. In the UK there were 1481 production units (number of companies not stated) with 87,300 total staff. Half of the companies employed less than 10 staff, a quarter had between 10 and 50 staff and 3% employed 500 or more. Four of the 10 EC countries did not have seasonal working in their meat industries, but it was reported as a major feature in Ireland – as it is in New Zealand.

In seven countries pay was linked directly to productivity, most markedly in Denmark. Nossent et al. (1995) also found the meat industry across Europe to have a higher than average labour turnover and to be considered unattractive to workers. The industry was reported to operate on very tight profit margins due to international price competition, strict hygiene standards and demands on quality from the big supermarket buyers. These pressures reduced ability to invest in new technology and made survival in the market difficult – especially for the smaller companies.

It should be noted that in this international review of the literature, definitions of key terms actually embraced by the authors will vary, and not just between those publishing in different languages. ‘Ergonomics’ for example is seen as encompassing work organisation factors in Europe and Australasia, but generally not in English-speaking America and Canada. Similarly, there can be variations in both diagnoses and body areas involved when describing MSD, making detailed comparisons between studies difficult.

1.2 Extent and cost of MSD in meat processing

In New Zealand the problem of musculoskeletal disorders among meat processing workers is substantial. Any gains that can be made in MSD reduction in the meat industry here in New Zealand will have a larger proportional national impact than it would in Europe however, as the New Zealand meat industry employs a markedly larger percentage of the total national workforce. New Zealand meat processing employs 1.5%, in the ten European countries surveyed by Nossent et al., in 1995 the figure ranged from 0.3% (Netherlands) to 1.0% (Germany).

Industry MSD incidence rates, as calculated from an analysis of ACC work-related entitlement claims and Statistics New Zealand data for industry working populations, show the meat processing sector has twice the MSD incidence rate for claims to ACC than the next highest incidence industry, and the second highest increase in number of claims since 2000/2001. Overseas the picture is similar. The Australian meat processing industry was classified as one of the highest risk for sprain and strain injuries, with estimated direct cost of injuries of \$300 million per year (Caple, 1992). Worksafe Australia reported in 1995 that the meat industry had an overall claim incidence rate five times greater than the national average, and that approximately one third of these were work-related upper limb MSD. Waniganayake & Steele (1990) confirmed the poor performance of the industry in the Australian State of Victoria specifically.

In Europe, Buckle and Devereux (2002), and also Nossent et al. (1995), report that for work-related upper limb disorders (WRULD) a lack of standardisation in reporting systems makes international comparisons difficult. This was also the conclusion of van Eerd et al. (2003), who in an international comparison of twenty seven MSD classification systems found that, “..the lack of a universally accepted classification system for MSD has limited both research and resulting efforts to reduce their burden.” (p. 935).

Broberg (1996) suggests that variations in diagnostic systems in compensation system design influences reporting behaviour in Scandinavia. In Norway for example 16% of neck and upper limb MSD are considered to be work-related, 40% in Denmark and Finland, and 70% in Sweden, the extreme variance of which Broberg suggests may be attributable to claim ‘migration’ between claim categories.

In the USA, meat packing plants had the highest incidence rates of disorders associated with repeated trauma in private industries in 2002 with a rate of 812 cases per 10,000 full-time workers (Bureau of Labour Statistics cited in Piedrahita et al., 2004). As a rough comparison, the figure for all US industries in 1987 was 10 per 10,000 (Riley, 1998) - eighty times less.

Bureau of Labour Statistics figures showed that the meatpacking plants also had the highest rates in the US for the seven consecutive years up to 2002 (Genaidy et al., 1995). The full costs to the companies including lost production for a carpal tunnel syndrome case were estimated (Riley et al., 1994) at US\$40,000 typically, and up to as much as US\$100,000.

In Canada, meat and poultry processing are reported as the highest risk industries for work related MSD among workers' compensation board claims (Yassi et al., 1996). Drewczynski & Bertolini (1995) of the Canadian Centre for Occupational Health and Safety (CCOHS) point to the cold environment combined with poor tool/plant design and the lack of training and education about MSD in the upper limbs as contributory factors.

Estimates of indirect costs of occupational MSD to those injured, their families and their employer vary a lot. ACC in New Zealand suggest a figure of 3-12 times that of the direct costs. The UK Health and Safety Executive cited in Tomoda (2000) suggest that with all knock-on costs including adverse affect on company image for the consumer, the cost of accidents could be as much as 37% of profits, 5% of operating costs and 36 times the insured cost. Tomoda also notes that based on data from a number of countries, disease cases typically costs two or three times as much in lost time as injuries. Assuming that the definition of disease adopted for this study includes slow-onset MSD - gradual process conditions (GPC), this may partially explain the overall trend of a global reduction in the incidence of compensation claims for meat and poultry and seafood processing, - but an increase in the total cost of compensation paid and days lost.

1.3 Body parts affected

The literature indicates that MSD in the meat processing industry most commonly affects the upper extremities including the shoulders and neck. Most cited conditions include epicondylitis and tenosynovitis (Kurppa et al., 1991; Viikari-Juntura et al., 1991), carpal tunnel syndrome [CTS] (Yassi et al., 1996; Frost et al., 1998; Gorsche et al., 1999; Isolani et al. 2002), tendonitis (Yassi et al., 1996), and trigger finger (Gorsche et al., 1998). The neck and low back are recognised as further sites of MSD among meat processing workers (Roto & Kivi, 1984).

Kurppa et al. (1991) carried out a 31 month follow-up of 377 workers in strenuous manual jobs and 338 workers in manually non-strenuous work in a meat processing factory. The annual incidence for tenosynovitis or peritendinitis was less than 1% for employees in non-strenuous jobs, 23.5% for female packers, 16.8% for female sausage makers and 12.5% for male meatcutters. The annual incidence of epicondylitis was 1% for employees in non-strenuous jobs, 11.3% for female packers and 6.4% for male meatcutters.

Magnusson et al. (1987) surveyed 73 butchers in Sweden to determine frequency of physical symptoms and found that 92% of those surveyed had experienced pain in any part of the body in the last three months. Most commonly reported was pain from the hands and wrists (about 60%) and from the shoulders and low back (about 55%). Pain in the elbows occurred in 40%. Almost 80% had pain from more than one region, the most common combination being pain from the neck and one or more joints of the arm.

Riley (2001) refers to a paper by Frost and Andersen (1999) that links working with the arms elevated, as on rail boning, with a condition known as Shoulder Impingement Syndrome (SIS). This is also reported as a common diagnosis among boning workers at a company in the UK with a moving chain system.

2. Key risk factors for MSD in meat processing

2.1 Introduction

The Department of Labour (OSH, 1997) in New Zealand categorises the risk factors for MSD in meat, poultry and seafood processing under: work organisation and scheduling, poor postures, task invariability, static loading, forceful movements, awkward postures, fit/reach/see, cold and vibration, psychosocial factors, product factors, and individual behavioural characteristics.

Malchaire et al. (2001) systematically reviewed all industry-based epidemiological studies of neck/shoulder and hand/wrist MSD in the previous 15 years. They concluded that the evidence was not strong enough to link specific situations in industry generally with specific disorders, and that questions relating to a person’s weight and hobbies outside work could be completely abandoned as irrelevant in future studies. By contrast their findings provided strong justification for interventions targeting biomechanical and organisational factors

Waniganayake & Steele (1990) in their study of 29 abattoirs in Australia identified high frequency handling, awkward grips, forward reaching, stooping and twisting, workstation design and handling of heavy loads as the most commonly occurring manual handling risk factors.

Nossent et al. (1995) observe that in Europe ‘the predominantly Tayloristic production line work and hierarchical organisation structure result in hazards, such as lack of autonomy and control over one’s work, strenuous work rhythms and time constraints, short-cycled repetitive work, and highly divided work with low job content’. They identify four high risk groups on the European plants: slaughter workers, boners, production line (packing) and women generally; and nine overall risk factors. Of these nine, five relate to the physical work environment, one to organisational constraints and three to the social work environment. The specific risks identified in their study of the meat industry in ten countries of the European Union are shown in Table 1.

Table 1. Main Risk Groups, Risk Factors and Health Problems. From (Nossent et al., 1995)

| Main risk groups | Main risk factors | Main health problems |
|-------------------------|---|--|
| Slaughter house workers | Biological agents Musculoskeletal loads Noise Climate factors Lack of autonomy High work pace Time constraints Repetitive work Low job content Unsafe conditions | Accidents and injuries Skin diseases Infectious diseases Hearing loss Musculoskeletal disorders |
| Production line workers | Biological agents Musculoskeletal loads Noise Unsafe conditions | No data, but likely: Accidents and injuries Skin diseases Infectious diseases Hearing loss Musculoskeletal disorders Respiratory disorders |
| Boners | Biological agents Musculoskeletal loads Noise Climate factors Time constraints Repetitive work Unsafe conditions Payment on production basis | Serious injuries Cut and stab injuries Repetitive strain injuries |

French researchers Loppinet and Aptel (1997) conclude from their literature review that the main risk factors for MSD in meat plants are understood, but that their interactions and methods of assessing relative importance are less well established. They conclude that therefore a broad and systematic approach must be taken that targets all risk factors.

Riley (UK), in his 1998 review of the literature on MSD in de-boning work, also concludes that there is general agreement on the main risk factors that have led to the high incidences of MSD in this industry sector around the world. He groups the acknowledged MSD risk factors under the following headings:

- Repetition
 - Repeated actions, short work cycles and limited range of movements
 - Speed of working
- Force
 - Force applied in order to cut
 - Grip force
 - Force applied with non-knife hand
- Static Posture
- Low temperature
- Lack of recovery
- Work organisation
 - Lack of training
 - Poor medical management
 - Pay - piecework and team bonuses

In the following sections, the literature on the generally agreed risk factors and risk multipliers are discussed in more detail.

2.2 Risks from repetition and speed

The Department of Labour (OSH, 1997) suggests that the careful regulation of line speed is critical for keeping tasks sustainable both for those working on them, and those affected by their output (e.g. packers). Factors which encourage an increase in line speed (such as piece-rate payment) can make tasks physically unsustainable, particularly where other MSD risk factors are present, for example, repetition, force, lack of skill etc. Repetitive tasks expose the same body tissues to repeated actions. This can become problematic where repetition occurs for long periods or where work speed increases so that recovery time is lost. Furthermore, as part of the strict hygiene requirements for export meat, there are maximum times allowed for the product from the chillers or slaughter floor to pass through the milder ambient conditions of the boning room. This can influence speed of work, as breakdowns or other hold-ups for any reason can result in high paced efforts by the labourers/packers in particular to get the product through in time (Tappin et al., 2006). Frost et al. (1998) found elevated risk of carpal tunnel syndrome among slaughterhouse workers which they associated with exposure to combined forceful and repetitive manual movements.

2.3 Risks related to force and posture

Awkward or static work postures, forceful movements, repetition and lack of recovery are generally accepted risk factors in meat de-boning work (OSH, 1997; Magnusson et al., 1987; Riley, 1998). OSH (1997) notes that poor postures may result from ‘poor design of equipment and facilities; a lack of education, training and knowledge; or a general lack of ability to sense the state of one’s own body.’ The OSH Guide also points out that external variability in the nature of the product (e.g. chilled versus hot boning) and the environment (e.g. working on a slippery floor) will have significant bearing on internal forces required.

Marklin & Monroe (1998) suggest that few studies have been undertaken that quantify the biomechanics of the upper extremity among red-meat packing workers. However, there have been considerably more papers published on biomechanics than on other factors such as work organisation for example.

A questionnaire survey and subsequent workplace analysis of 73 butchers in Sweden observed that high forces occurred during meat cutting, frequent and heavy manual handling and bad working postures (Magnusson et al., 1987). Magnusson found that the large pieces of meat requiring cutting resulted in high knife forces which increased when the arm was required to work in an end-range position. Static posture and resistance of the meat caused high loading on the shoulder. High loading on the low back was caused mainly by the working postures, with lifting using a combination of flexion and rotation also common.

In a retrospective study of a cohort of workers (n=1141) employed in a meat processing or chemical factory, Frost & Andersen (1998) used video recordings to obtain information on the repetition of wrist movement and estimate proportion of time wrist held in non-neutral positions. Video recordings were made from 2 positions to register frequencies of wrist flexion and extension (>15deg) and ulnar deviation (>20deg), and the duration of wrist positions out of neutral in the same directions. Neurophysiological examination was also carried out. They found an elevated risk existed for CTS among slaughterhouse workers (1.6% of reference group, 5.1% of non-deboning slaughterhouse workers and 7.8% of the deboning slaughterhouse workers). Frost & Andersen considered daily high-velocity and high-force manual work to be a risk factor for CTS. Further to this, they identified an increased risk for CTS in the non-dominant hand among workers involved in deboning tasks. They noted that slaughterhouse workers used their non-dominant hand to assist constantly and actively in tearing, lifting, turning and holding the meat parts which weighed between 6 – 12kg.

Frost & Andersen also assessed shoulder work in 48 tasks carried out by the meat processing workers. The analysis, which represented 90% of jobs held by slaughterhouse workers, showed the upper arms were raised to at least 30 degrees for about half the working time, with arms raised above 30 degrees approx 10 times a minute. The prevalence ratio for shoulder impingement syndrome among those currently working was 5.27 (95% CI: 2.09 – 12.26) and 7.90 (95% CI: 2.94 – 21.18) among former slaughterhouse workers. The study concluded that the sustained intensive shoulder work as seen in the Danish slaughterhouses was a risk factor for shoulder impingement syndrome.

Oxenburgh (1991) also observed the involvement of both arms during meat processing; one arm and wrist required to adopt a static posture to hold the meat steady, while the other arm was used to cut meat with the wrist in ulnar deviation and out of its strongest midline position.

Falck & Aarnio (1983) assessed force requirements with workers during de-boning in two Swedish slaughterhouses using EMG of the left and right short flexor carpi radialis muscles over a period of six hours work. They observed that muscles on the left side were exposed to a higher level than those on the right holding the knife. Falck & Aarnio concluded that both the level and duration of exposure were considered important in the development of CTS. In a study by Christensen & Larsen (1995), mean force requirements on the forearm flexors muscles (n=45) were assessed by EMG during deboning work. The results showed static activity ($p=0.1$) of between 8% and 9%, a median activity ($p=0.5$) of between 25% and 30% and a peak activity ($p=0.90$) of about 60% of a mean maximal hand grip of 54.6kg.

Marklin & Monroe (1998) compared the wrist motion of nine workers using Whizzard-type knives for bone-trimming in one US plant, with wrist motion benchmarks from workers who performed hand-intensive repetitive work in jobs that were of low and high risk of hand/wrist MSD. The comparison showed that the right-hand motions when trimming meat off the bone were in the high-risk group of MSD as compared to the manufacturing industries benchmarks. The acceleration and deceleration of firstly the hand holding the knife and secondly the non-dominant hand used to grab the bone, hold it then toss it back on the conveyor was likely to result in reaction forces on the median nerve, carpal bones and flexor retinaculum in both hands – as identified in earlier work by Schoenmarklin & Marras (1990).

Van der Doelen & Barsky (1990) observed that the force applied by a worker to cut meat depended on the position the wrist takes with respect to the arm, the distance from the wrist to the point of force application, the sharpness of the knife being used and the toughness of the product being used. A blunt knife or tough or semi-frozen meat will increase the force required to cut meat.

In an overview of repetitive strain injury in the meat processing industry, Van der Doelen & Barsky (1990) considered that using the same knife to perform a range of different cuts results in the workers' hand, wrist and arm actions having to accommodate differences in the height of the cutting surfaces and contours of the meat. They recommended that a variety of knives should be available to allow for a neutral wrist posture when performing cuts and the height and slope of the work surface should have adjustability to improve the alignment of the hand and wrist. The frequency with which meat workers are required to lift and hang meat on an overhead line was also commented on by Van der Doelen & Barsky (1990), who suggested a relationship existed between these tasks and the adoption of frequent asymmetric posture. Lifting both arms repeatedly to cut parts from the carcass above the mid chest height was also considered likely to lead to static muscle work, discomfort and fatigue.

2.3.1 Protective gloves

The thickness and design of gloves affect grip force by changing the sensory feedback from a tool or object. Introduced to reduce knife cuts to both non-knife and knife hands, gloves may therefore act as an MSD risk factor by increasing the magnitude or duration of grip forces applied to the knife and/or the piece of carcass being cut. The use of gloves has been shown to have this effect generically (Fleming et al., 1997), but not specifically in the meat industry context. A recent study by Claudon (2006) however found that use of Kevlar fibre gloves increased friction between the hand and knife handle, but with no significant differences in EMG values of forearm and shoulder muscles.

Wallersteiner and Arnold (1989) conducted a laboratory study that compared the ability of the bare hand to generate torque on a knife handle with four different glove ensembles (cotton liner/nitrile outer used in the beef and pork processing industries, two other glove types were trialed as ‘improvements’). No statistical differences were demonstrated (under ‘dry’ conditions – significant results are reported for the ‘greasy’ condition though. i.e. sometimes gloves are better than bare hand). Fatigue and other interacting task factors found in the actual workplace were not included as variables however.

In New Zealand the potential benefits and risks associated with the use of protective gloves was examined during the meat industry 1993-6 study (Slappendel et al., 1996). Greenslade et al. (1998) had also noted that the surgical gloves sometimes used over the cut resistant gloves could improve hygiene performance adequately but were found to be slippery in combination with blood and fat – further increasing the grip forces needed to maintain the same ‘feel’ and control. No quantitative testing of forces appears to have been conducted with the actual glove ensembles used in New Zealand. A study for Meat New Zealand on gloves in pre-inspection slaughter areas in adult beef processing plants by Khela & Legg (1998) included a comparison of microbial counts between gloved and bare hands under laboratory conditions. The gloves used in the tests were not of a kind used in the boning or slaughter departments of meat processing plants however.

2.3.2 Knife design

Grant & Habes (1997) conducted surface EMG studies with subjects undertaking simulated meat cutting tasks under laboratory conditions and concluded that musculoskeletal stresses in meatpacking tasks can be altered through tool and workstation redesign. In their overview of risk factors within the meat processing industry, Van der Doelen & Barsky (1990) noted equipment (i.e. knives, automated tools and gloves) to be a factor in the development of MSD. Longer knives were acknowledged to result in higher torsion forces on the wrist when the cutting action is performed near the tip of the blade. Knife shape and stiffness also influenced the force generated with knife handle shape, size, texture and material affecting the force generated when cutting meat. Factors relevant to automated tools and the risk of MSD include vibration and weight. Claudon (2006) discusses the need to improve knife design, essentially considering: friction between handle and operator’s hand, and handle hardness, which are considered too low and too high respectively. He goes on to cite Bucchholz et al. (1988) describing that low handle friction causes the operators to grip more firmly, increasing the risk of MSD. Cutting forces also vary according to blade inclination (Marsot et al., 2007).

2.3.3 Knife sharpness

Claudon (2000) noted that of 196 butchers interviewed in their study in France, only 16% reported having been trained in sharpening and maintenance, and 42% complained of the blade not being sharp enough. Marsot et al. (2007) describe how use of an insufficiently sharp knife results in a higher force applied by the operator, and an increase also in cutting time.

Claudon and Marsot (2006) measured muscle activity using electromyography (EMG) and a quantifiable method of determining blade sharpness. The sharper blade reduced EMG activity levels in most muscle groups measured, but very high activity was recorded for the extensor digitorum communis (EDC), even when the knife sharpness was excellent. The likelihood of forearm discomfort and injury therefore remains high, and suggests that factors other than knife sharpness need to be addressed.

2.4 Risks due to lack of recovery

OSH (1997) suggests that problems related to task invariability can apply to either physiological or psychological aspects of jobs.

Temmyo & Sakai (1985) noted that vital inherent rest pauses in the work cycle seen in traditional autonomous butchering ‘work teams’ were largely missing from tasks in plants in Japan and New Zealand which were using a chain system.

Christensen et al. (2000) explored the effect of different work/rest patterns as risk factors for developing MSD. Industry guidelines recommended meat cutters to debone the meat slowly followed by a shorter rest period, rather than complete a task cycle fast and have longer breaks between pieces, and to continue in this way for the whole day. The task time for meat cutters was observed to vary between 60 and 240 seconds depending on different types of meat to be deboned (Christensen & Larsen, 1995). The study used self-selected “slow” and “fast” groups of meat cutters and found no difference existed in the mean muscle activity levels. Also noted was that the three different types of boning task appeared to be performed with a stereotyped muscle activity pattern with only small variations for the forearm muscles. Regardless of large differences in the work/rest pattern between the two groups, no differences were found in any of the measured acute physiological responses (HR, BP and EMG). The comparative experience/skill level of the two groups is not described however, which may be relevant, as may the amount of rest time achieved by the slower group between task cycles. There was no comparison between those achieving rests and those who did not rest at all.

Dababneh et al. (2001) studied the impact of frequent short breaks on the productivity and well-being of 30 workers in a meat processing plant. Two regimes were compared. The first regime consisted of twelve 3-minute breaks during the workday and the second four 9-minute breaks over the day. The results showed that production was not negatively affected by the breaks and that the 9-min break improved discomfort ratings for the lower extremities. Workers mostly preferred the 9-minute break schedule over a more fragmented short frequent break programme.

Seasonality results in compression of work into less months of the year, with more work hours and less downtime (ie increased task exposure). Analysis of recent ACC and meat processing injury statistics indicated that most reported injuries occurred between Jan-April (Tappin et al., 2005).

2.5 Risks from working in cold temperatures

As part of the export food industry, meat and seafood plants have strict standards to comply with - such as upper and lower limits for the ambient temperature in the boning room, which can conflict with healthy and comfortable working conditions. Coldness, high humidity, draught and temperature fluctuations are identified as especially problematic factors by Nossent et al. (1995). OSH (1997) suggests that the draughts from compressing machinery and elsewhere can be so great as to reduce the blood flow to the extremities, which can increase the risk of MSD. OSH also links cold, wet conditions with vibration as a combined high risk scenario for MSD.

Enander (1988) states that the working environment, which is often cold and wet, is a risk factor resulting in numbness and stiffness in the hands and fingers, which can act to impair manual dexterity.

Cold cutting rooms were noted to have increased thermal discomfort and to expose workers to cold stress and strain, elevated air humidity and low floor temperatures (Ilmarinen et al., 1990). Piedrahita et al. (2004) carried out a cross sectional epidemiological study (n = 162) to explore the relationship between MSD and cold exposure in a large meat processing company in Colombia. A comparison was made between workers in very cold areas (+2degC) n=50 and less severely exposed areas (+8 - +12degC) n=112. A high prevalence of MSD was found among the more exposed workers, especially for neck (prevalence ratio =11.2 (95%CI 1.3 – 93.4)) and low back symptoms (prevalence ratio = 4.5 (95%CI 1.6 – 12.4)).

2.6 Risks from noise

Floru (1994), cited in Loppinet & Aptel (1997), states that apart from harmful effects on hearing, noise can also stress the operator, influence balance, and bring on fatigue as well as diminishing performance.

Noise is identified by Nossent et al. (1995) as a risk factor in MSD, as well as in other health, psychological and communication problems. The Australian National Guidelines for Health and Safety in the Meat Industry also identify that poor control of noise can create stress leading to tiredness, irritability and headaches. Balance and concentration may also be affected (AMIEU, 1995). The wearing of hearing protection reduces interpersonal communication drastically – impacting on hazard management, teamwork and effective rotation (AMIEU, 1995).

Caple (1994) reported that a high proportion of work areas in Australian abattoirs have noise levels in excess of 85 decibels (dB(A)). Peak levels of 111 – 140 dB(A) were from metal on metal contact as when dropping hooks into chutes and in the sticking areas. Typical ‘equivalent level of sustained noise’ or L_{eq} values were around 96dB(A).

2.7 Lack of training

New workers are especially at risk as not only do they lack the skills, but also the familiarity with the surroundings; “When someone’s never been in a packinghouse before, and then suddenly they’re surrounded by blood, guts and gore, they may go into shock for the first two weeks” (Mumford, 1996).

Lack of skills training is regularly cited as a factor in poor knife condition. Claudon (2000) noted that of 196 butchers interviewed in his study in France, only 16% reported having been trained in knife sharpening.

Nossent et al. (1995) note that the deficiencies in training are found not only on the floor, but also in management. Lack of training at management level, they report, is likely to affect all levels of the industry operations including: physical hazards, work organisation, work relations and company health and safety policies.

2.8 Poor Medical Management

OSH (1997) in New Zealand set out guidelines for early reporting, management of early signs and symptoms, and rehabilitation but does not discuss directly the implications of neglecting these. The Guide also reports that ‘illness beliefs’ are seen by many occupational medicine practitioners as the most important factor in the return to work by people with MSD. Illness beliefs include the perceptions that pain is harmful or disabling, resulting in fear-avoidance behaviour such as guarded movements and fear of movement.

2.9 Psychosocial factors and pay structure

In New Zealand most meat plants shut down for a period during the middle of the year (ranging from weeks to several months). Closedown and start-up is progressive however, and so full tally with all chains running and staffing at 100% is achieved for a substantially shorter period. This contribution to staff retention problems is not commonly reported in other countries. Nossent et al. (1995) report that of ten European countries surveyed, only Ireland operated on a seasonal pattern that resulted in significant numbers of staff not having permanent contracts – which is similar to the New Zealand meat industry.

Historically the New Zealand meat industry paid above-average wages, and so good staff were less easily lost to other employers outside meat processing than they are now. The attractiveness of the meat industry has also diminished in other countries. In the USA, meat processing plants paid 110% of the national average for manufacturing workers in 1963, but by 1990 it was down to 71% due to recessionary pressures on companies to cut costs and increase production (NIOSH, 1994). These and associated factors contributed to deterioration of industrial relations and increased injuries, illnesses and worker turnover. There appears to be growing research interest in this area. Nossent et al. (1995) report on the variations of structures in plants across ten European countries that will have significant bearing on remuneration and contract related factors. Belgian plants for example have contracted private providers on site supplying boning and slaughter staff who work on the client company premises.

Graves et al. (2004) comment on the relevance of psychosocial factors and included psychosocial questions in their development of risk filter and risk assessment worksheets for HSE guidance. Devereux et al. (2004) investigated reported stress and the link to reported musculoskeletal complaints among 8000 workers in the UK. The study showed that psychological stress reactions (depression, psychosomatic symptoms and perceived life stress) may independently effect the development of musculoskeletal complaints. Perceived job stress may also increase the risk of developing musculoskeletal problems when exposed to physical and psychological workplace stressors.

OSH (1997) states that pay structures with bonus systems can lead to people driving themselves too hard, and that working beyond their capacity is a cause of MSD.

Production pressures are also suspected to be a factor in grip forces used. McGorry et al. (2004) found that in their laboratory based study of non-meat workers on a simulated meat cutting task, the variable of asking subjects to work as though they were getting paid by the amount of cutting they did produced the biggest increase in cutting force applied.

Nossent et al. (1995) note that workers in the meat sector often lack information and feedback from management and the formal opportunity to participate in innovation projects, quality circles and suchlike. Health data are not available but they identify this lack of involvement as a risk factor and judge that stress and dissatisfaction are likely to occur. They also found that unequal opportunities exist for women in the ten European countries surveyed. Again, health data were not available but they identify this as a risk factor and judge that stress and dissatisfaction make MSD symptoms more likely to occur. No supporting references are given.

2.10 Individual factors

The relationship between the performance of work and MSD is now well evidenced, but factors outside the workplace may influence the onset of MSD or exacerbate conditions (Buckle & Devereux, 2002). Individual worker characteristics, such as age, gender, physical medical history etc, may also affect MSD risk within the workplace, for example by modifying the way in which the work is performed (Buckle and Devereux, 2002; NIOSH, 1997).

In New Zealand, OSH (1997) simply states that ‘a variety of factors may play a part here i.e. individual, physiological, and psychological characteristics’. The authors note that the research evidence is scant, but suggest nevertheless that: a tendency to take on too much work, being a competitive perfectionist, to be unaware of early warning signs or ignore them, or to have a poorly developed ability to sense the state of one’s muscles - are risk factors.

The Guide also suggests that non-work settings matter as people react to social stressors at home as well as at work, which can act as a cause of OOS (MSD) when their ability to cope is exceeded. The extent to which non-work stressors contribute to MSD at work is unknown however.

3. Interventions for reducing MSD in meat processing

3.1 Introduction

OSH (1997) places work organisation and task scheduling at the head of their list of control factors. This acknowledgement of the need to address high level issues is reflected generally in the international literature and most notably in the French-speaking countries. The MSD risk factors and possible risk reduction measures identified in the literature by the Health and Safety Laboratory in the UK are shown summarised in Table 2.

Table 2. Risk factors and possible risk reduction measures. From Riley (2001)

| Risk Factors | Possible risk reduction measures |
|---|---|
| Repetition | Slowing of work rates Job rotation / Job enlargement Rest breaks / Micro-breaks Training and education Automation / Mechanisation |
| Speed of working | Slowing of work rates Slowing conveyor / floating Chargehand Rest breaks / Micro-breaks Training and education Payment schemes |
| Force application in cutting and gripping with non-knife hand | Sharpness / sharpening regimes Knife handle design / knife blade design Glove design / weight / fit / tensioners Workstation design Mechanisation / support cradles / tensioners Temperature of meat Rest breaks / Micro-breaks Training and education |
| Postures | Workstation design Rail height adjustment Support cradles Knife and tool design / hooks Training and education Mechanisation |
| Temperature | Temperature management Clothing Glove design / thermal properties Rest breaks / Micro-breaks Training and education |
| Recovery (lack of) | Rest breaks / Micro-breaks / Exercise breaks Work hours Training and education Pay schemes |
| Training (lack of) | Training in musculoskeletal problems Training in good technique and posture Training in sharpening Management of new recruits |
| Medical Management | Assessment Monitoring Management system / policy Rehabilitation system |
| Piecework and bonuses | Reduce production related payment |

3.2 Adopting a systems approach

OSH (1997) in New Zealand emphasises the role of work organisation and task scheduling more strongly than is found in the international literature generally. Supervisory structures, chain speed, task description clarity, monotony, the effect of busy seasons on workload and the need for overtime and shiftwork are included under this. Less emphasis of organisational factors in the international ergonomics / human factors literature could be due in part to English-speaking North American researchers regarding work organisation as falling outside their definition of ergonomics.

French researchers Loppinet & Aptel in their 1997 literature review emphasise the need for a global approach to tackling MSD risk factors. They cite Toulouse et al. (1991) in calling for interventions packages that look outside the plant if required. For example, an upstream intervention could be to modify the condition of the animals being sent by the suppliers to ease workloads within the plant in question. A downstream intervention includes working with customers to get a balance of fast ‘just-in-time’ service with sustainable working patterns on the plant – rather than highly variable hours and work pace.

The French literature on MSD also stresses the need for accepting a multi-factorial aetiology. In a dynamic environment such as meat processing, MSD cases are considered to be very rarely the result of a single factor. To quote Loppinet & Aptel (1997, translated), “MSD is not included in a model where a [single] cause produces an effect but a [it is] within a probability frame in which multiple factors interplay, occupational factors, but equally those external to an occupation. Each factor more or less coincides with the appearance of these pathologies. It follows that MSD are multi-factorial illnesses with an occupational element”.

3.3 Addressing psychosocial factors

Loppinet & Aptel (1997) note that “the world of the meat chain appears ‘cold’ in the literary sense as well as in the figurative sense.” Several authors comment on the psychosocial stress risk factors associated with the nature of the work and the difficulties in communication (Bongers et al. 1993). Loppinet & Aptel refer to work by Touzart (1986) in which he proposes modifications to the layout of the plant floor and equipment to improve communication and lessen the sense of isolation of the personnel.

3.4 Rest breaks, micro-breaks and exercise breaks

Sundelin and Hagberg (1989) cited in Genaidy et al. (1995) distinguish three types of breaks:

- Passive breaks, during which the operator may simply relax at his post
- Active breaks, during which operators are required to stretch and carry out other ‘gymnastic’ movements
- ‘Free’ breaks, where the operator stood up and walked in the aisle

In 1967 the Gear Meat Company in Petone near Wellington, New Zealand reported reductions of lost time accidents from 20 per 100,000 work hours in 1962 to around 8 per 100,000 five years later (Gazette, 1967). National incidence rate for the meat industry as a whole was 14.7 in 1962, and so the plant appears to have progressed from being well below average to being a high performer. The improvement was attributed to a safety programme that included reduced manual handling, and the introduction of five minute breaks at the end of each hour - in addition to the normal breaks. The company reported improved production, and less of the types of injuries which they had identified to be linked to progressive fatigue during the day.

The cost of the safety programme was reported to be outweighed by the savings in lost production time, recruiting, equipping, clothing and training new staff.

Genaidy et al. (1995) introduced active (stretching) micro-breaks into a plant for a period of four weeks. The staff were able to select their own micro-break times based on perceived discomfort, in spells of two minutes for up to 24 minutes (in total) which was 5% of their working day. They reported that significant reductions in levels of perceived discomfort were recorded. No objective measures were used. It is not explained how this regime of self-determined 2 minute breaks was made possible for staff working on the chain.

Objective studies that may help in the design of optimal, but workable, work-rest patterns in the New Zealand meat industry are limited. Most have been conducted in the laboratory rather than out on the plants. Wood et al. (1997) reported on a laboratory study with college subjects of three work-rest schedules using a hand dynamometer. The least fatiguing (optimal) pattern tested was found to be medium force contractions with medium duration rest period. The most fatiguing was applying maximal force for short bursts with long rests in between. Low force-short rests was marginally more fatiguing than the optimal.

Henderson et al. (1994) cited in Loppinet & Aptel (1997) notes, as a number other authors do, that active breaks are unpopular with staff and that passive ones are likely to be the most effective for combating MSD in meat processing.

In an interesting paper by Dababneh et al. (2001), the impact of having short breaks every half-hour or longer rest breaks each hour on the productivity and well being of a group of 30 workers in a meat-processing plant was studied. Both break schedules provided 36 min of extra break time over the regular break schedule (30-minute lunch and two 15-minute breaks). In the first experimental rest break schedule, workers were given 12 x 3-minute breaks evenly distributed over the workday (3-minute break for every 27 minute of work). In the second schedule, workers were given four 9-minute breaks evenly distributed over the workday (9-minute break every 51 minute of work). Outcome measures included production rate and discomfort and stress ratings. Results showed that neither of the two experimental rest break schedules had a negative effect on production, and the 9-minute break schedule improved discomfort ratings for the lower extremities. The workers in the study mostly preferred the 9-minute rest break schedule, indicating that workers in general might not as readily accept fragmentation of break time into short, frequent breaks. The paper does not state whether the extra 36 minutes were gained by increasing line speed or simply extending the working day.

3.5 Job rotation and job enlargement

Loppinet & Aptel (1997) comment that job rotation, while widely endorsed in the literature, is only an intermediate step prior to the development of solutions that will eliminate the risk at the workstations concerned. To be effective in providing rest for the various muscle groups job rotation and job enlargement has to be designed carefully after a prior study that analyses the specific task demands at each station.

Much of the literature on job rotation originates from the French-speaking countries and relates to the poultry industry rather than red meat processing.

3.6 Improving knife sharpness and design

Standards have been developed for knives in the industry (e.g. Standards Australia, 1992), but the literature suggests that the provision of guidelines alone is not enough to provide minimum standards for all staff.

Greenslade et al. (1998), identified the knife as the ‘single most critical tool to get right in the industry’. They note that in order that no one is struggling along with a blunt knife the staff need: a knife of good enough quality steel, adequate sharpening skills for the task, the tools to do it (grinder, setter, stone, etc), and enough time to actually carry it out. Slappendel et al. (1996a) noted that one risk factor presented by work compression was the inability of some staff to find time to look after their knife. Slower staff, such as: those newer and less experienced, older and less fit, or those simply in the highest workloads points in the line frequently did not have time to steel their knives. Greenslade et al. called for systematic studies on optimising knife design and edge maintenance for specific tasks in New Zealand meat plants. Quantification of methods in particular was needed to get beyond the folklore approach to knife sharpening seen as prevalent in the industry at the time.

Greenslade et al. (1998) also report on a prototype design where boning room staff informally trialed a new design based on staff preferences. A preferred blade was re-matched with a different handle, the handle having been also modified through simple changes in the production process to increase diameter. Around this time, publications were released on the use of knives, by ACC and the trade training organisations (Rata, 1995; NZQA, undated). Work on simplified sharpening systems was undertaken by MIRINZ (Dowd, 2001).

Both blade and handle have been experimented with, separately and jointly, and their link with MSD in meat processing continues to attract research attention (Loppinet & Aptel, 1997). This may be due in part to being a relatively easy aspect to isolate and study remotely from plants. The vast majority of these studies have been conducted off-line (either in rooms away from the chain or laboratory-based) and with no subsequent live testing. The lack of consideration of other factors limits the usefulness of the findings to industry substantially.

These off-site studies have also tended to employ simulated meat cutting tasks (Hsiang et al., 1997) and latterly use clay tablets or fibreglass mesh rather than meat as the cutting medium for reasons of cost and uniformity (McGorry, 2001; McGorry et al., 2004). In some cases this makes the findings hard to generalise to tasks such as boning-out quarters of beef where two very significant factors are the three dimensional nature of the work, and the lack of homogeneity of the meat, bone and other tissues in the structures being broken down.

The Gear Meat Company in Petone in 1967 included the improving of the sharpness of knives used by new recruits as part of the successful safety programme (Gazette, 1967). It was reported that new employees did not sharpen their own knives until they had the skills needed to work at full pace on the chain. Skilled staff did all sharpening for them. It should be borne in mind however that this Gazette article was written by a staff member of the newspaper, and as usual for this medium, the methods of investigation and analysis are not stated.

Overseas, studies have concluded that both MSD and lacerations could be reduced by improved knife designs (Cochrane and Riley, 1986a and 1986b).

In a French-Canadian study on knife sharpening techniques 15 workers were assessed using video techniques in comparison to expert knife sharpeners. The authors Chatigny & Vezina (1992) concluded that there is too much variation in techniques and not all were effective. A number of authors have reported on attempts to quantify knife sharpness and effectiveness in meat cutting tasks. Several methods of measuring sharpness in the field are reported. Szabo et al. (1998) describe a system that measures the area cut by a knife into a carrageenan (seaweed extract) gel target for a controlled load at the handle. Blade edge angle (the shoulder) was found to be significant. A blade with a steeper shoulder cut less well initially but lasted longer, a shallower angle being sharper if the operator was able to keep it maintained.

McGorry et al. (2005) conversely found that blade edge angle made no significant difference to cutting time, mean grip force or cutting moment, but interestingly that a high polishing protocol to finish the blade did: cutting tasks were completed 25% faster with the polished blade. Marsot et al. (2007) however say that preferred knives do favour blade inclination whilst also limiting wrist radial deviation. They describe that the literature (Bobjer, 1989) supports a 15° blade inclination with respect to the knife handle axis. The Marsot study, which tested the effect of blade inclination on cutting performance, showed the cutting forces decreased according to blade inclination – they also indicated that a curved blade would further enhance this effect.

Occhipinti et al. (1993), carried out a comparative study of three different knife handle designs using EMG measurements of the upper arm. Subjects were experienced boning staff – but tested cutting meat in a laboratory setting. Findings confirmed that the upper arms were overworked, but were inconclusive on the role of handle design. The experiment was limited by not being subject to other relevant working conditions (e.g. pace, fatigue, noise, duration).

Fogleman et al. (1993) simulated two poultry de-boning tasks in the laboratory and evaluated the wrist angle and grip force while using 6 different knives. The straight knife performed the worst under all conditions tested, while -30deg blade was best for a dagger grip used during the table cut and +30deg blade was best for the hanging cut.

Claudon and Marsot (2006) measured muscle activity in the laboratory using electromyography (EMG) and a quantifiable method of determining blade sharpness. The sharper blade reduced EMG activity levels in most muscle groups measured, but very high activity was recorded for the extensor digitorum communis (EDC) (a muscle on the back of the forearm) even when the knife sharpness was excellent. The authors concluded that if field tests confirmed this to be true in actual work settings then interventions such as improved knife design and better work organisation would be needed as blade sharpness alone would not achieve the desired gains.

Armstrong et al. (1982) cited in Loppinet & Aptel (1997) advocate a knife with an enclosed handle similar to the protective ‘basket’ on a ski pole handle that enables the user to relax the hand fully without dropping the pole. This idea is in response to the problem also identified in New Zealand (Moore & Tappin, 1997) of the meat workers not actually relaxing the hand between cuts unless the knife is returned to the holster. This design however does restrict the ability of the user to change grip and so it could not be used in all tasks.

3.7 Automation, mechanisation and assistive devices

Nossent et al. (1995) present comparative data on meat industry output as a percentage of national Gross Domestic Product (GDP) and industry working population as a percentage of the total national working population. The German and New Zealand meat industries for example both generate roughly 1.7-1.8% of GDP. New Zealand use 1.5% of total national working population, Germany 1.0%. The extent to which this may be attributable to adoption of mechanisation are unknown. Differences in species processed and/or cut specifications would also factor.

Juul-Kristensen et al. (2002) compared the physical workload before and after the introduction of new technology in poultry processing. Cutting was identified as the most strenuous task of manual deboning. The muscular activity was significantly higher in cutting tasks in extensor carpi ulnaris, flexor carpi ulnaris and flexor digitorum superficialis during manual deboning when compared with mechanical deboning. However, while mechanical deboning moderately reduced peak forces the muscular activity remained high and higher levels of acceleration and repetition rates were introduced. Overall, the new mechanised technology had only a marginal effect on the risk factors associated with WRMSD during poultry processing.

3.8 Improving workstation design

The physical work place factors associated with an increased risk of work related musculoskeletal disorders are repetition, posture, force and vibration (NIOSH, 1997). Intervention studies should aim to improve all these physical factors, however there is insufficient scientific knowledge about the optimum work load for each single risk factor and for the interaction effects between them (Li & Buckle, 1999). Buckle and Devereux (2002) indicate positive results from various laboratory and field studies, showing reduction in exposure to biomechanical workplace risk factors following redesign of handtools or workstations.

Waniganayake & Steele (1990) identify the need to stabilise the work as far as possible, within the hygiene constraints, to reduce the force needed by the non-knife hand. They comment on the advantages of the cradle system for beef slaughter, and inverted dressing of sheep in this regard. They also note how difficult making the required changes to workstations can be in old premises.

Caple and Hodgson (1992) collated information on low-cost micro level solutions for workstation and tool design, and distributed this in Australia.

Comparative studies on different approaches to slaughter and boning that could identify usefully specific MSD risks tend to focus exclusively on production. For example, Brasington & Hammonds (1971) objectively compared traditional US table boning to the boning of carcasses on a powered rail - a new concept to them at the time coming from Australasia. Findings included a higher yield of total meat for the on-rail system, attributed by the researchers to the greater recovery possible by (lower-paid) trimmers with mechanical knives working on the more complete bones. Their quantitative methods maybe of interest in any future holistic studies examining: MSD risk, yield, speed and hygiene.

Anthropometric analyses which might shed light on mismatches between workers and their tasks or equipment ensembles in New Zealand are limited. Publications are piecemeal and plant-specific. Ford (1993) found that male standing elbow and knuckle heights were significantly lower for plant staff (5th %ile of 971mm) than for the New Zealand population estimates as whole (19-45 yr old males 5th %ile – 1035mm). There were no females in the study.

3.9 Reducing speed of work

Compression is the practice of reducing breaks to shorten the working day, and while attractive for some staff can cause difficulties for others who are struggling to keep up with the pace and maintain their knives. Slappendel et al. (1996b) report on a study conducted during the 1993-6 New Zealand Meat Industry Injury Prevention Project. Over two years the compression of Official Working Time in a lamb boning department was reduced from 17% to 2%. There was a halving of the overall Lost Time Injury Frequency Rate (LTIFR) for the room reported with the labourers in particular benefiting (60% reduction in LTIFR). The researchers concluded that work organisation improvements should not be overlooked as injury prevention interventions as they can achieve rapid results and need not be costly to implement.

3.10 Better training and education

During the same 1993-6 Project, a half-day interactive ergonomics awareness training session was run (Moore & Tappin, 1997). Content included practical demonstrations on: the importance of rest as a factor in maintaining high performance (using a biofeedback device on the knife and non-knife hand). Participants took part in a practical anthropometry study of 'how average they actually were - in comparison to how average they thought they were', in several key body dimensions. The rationale for this session, was that engineers and fitters designing and building plants had commented during the study that they used intuition and their own body as their guide and had found this adequate. The exercise provided objective feedback to these people on the accuracy of their intuition. The findings included that subjects generally believed themselves to be closer to the 50% percentile than they actually were, and also that a person of 95th percentile stature would also therefore be 95th percentile, or close to it in all other dimensions; which is not the case. Evaluation of this training indicated that these experiential exercises were more popular and more memorable than the theoretical components of the session.

In Canada the specific needs of new staff was addressed by a training package developed by a tripartite initiative (Mumford, 1996). In Ontario, tripartite industry-specific safety authorities have operated for several decades, funded largely by mandatory levies collected via the state insurer.

Off-line training away from the normal production pressures of the plant for new or returning staff has been experimented with in New Zealand and there is some research support for this approach as production pressures are suspected to be a factor in multiplying the grip forces used.

Shaw and Blewett in Australia (2001) emphasise the need for health and safety training plans to include all levels of the organisation, as analysis and interventions must extend system-wide to be fully effective. It is interesting by comparison to note that the proposed OSHA ergonomics (1999) rule in the USA required only ergonomics programme administrators, employees in problem jobs and their supervisors to be trained.

3.11 Improved glove design

Gloves are worn on the non-knife hand, knife hand, or both hands, to also address run-through cuts. The benefit of good glove fit for reducing grip forces is widely acknowledged, as are to a lesser degree the specific problems of non-knife hand work (Drewczynski & Bertolini, 1995); these are static loading and forceful movements when manipulating and ripping away the meat and other structures.

Anthropometric studies on glove fit and the hand sizes of meat workers that can assist in improved design are limited. The New Zealand estimates (Slappendel & Wilson, 1992) are ratio-scaled from British data. An unpublished 1996 study by Tappin & Moore (South Pacific Ergonomics Ltd) of New Zealand meatworkers found that the commercially available gloves in New Zealand were often too small in circumference at the knuckle. As a result many workers had to cope with a larger size which meant surplus mesh ‘dripping’ off the ends of the fingers which reduced dexterity and introduced additional risks when operating bandsaws and other plant. By contrast Johnson (1998) refers to an unreferenced anthropometric study of meatworkers overseas which indicated the need for extra small sizes - the meat worker population in his study being smaller than the target population of the manufacturers.

3.12 Noise control

Caple (1994) in his report Noise Control for Abattoirs, compiled a catalogue of practical measures to reduce the noise at source in plants. Interventions included the lining and insulating of hook chutes.

3.13 Reducing the impact of cold

Patry et al. (1993), cited in Loppinet & Aptel (1997) identifying two levels of further research needed regarding work in cold conditions. The first is to optimise the balance between meeting hygiene standards and minimising human discomfort. Touzart (1986), another French-speaker cited in the same reference reported that the raising of ambient temperatures by as little as 1 degree had been found to be beneficial. Secondly, Patry identified the need for more development in specialised protective clothing for the colder conditions in boning rooms and chillers.

Ilmarinen et al. (1990) undertook a project involving close co-operation between workers, safety officers, employers, research workers, designers and manufacturers to design and manufacture functional work clothing that increased the thermal comfort of workers.

3.14 Early identification and medical management

OSH (1997) in New Zealand set out recommended guidelines for early reporting, management of early signs and symptoms, and rehabilitation. An example of a rehabilitation programme is provided for employees returning after an absence. The use of Alternative Duties is encouraged.

Loppinet and Aptel (1997) stress that early detection of MSD is strictly a secondary level intervention. The primary risk factors should be addressed first. The evaluation work by Moore & Garg (1997) on a pork plant in the US may be an example of where early identification and medical management were the dominant successes in the programme; incidences of injury stayed consistent but total costs of all claims came down.

Discomfort surveys such as the Nordic Musculoskeletal Questionnaire (NMQ) are a method of subjectively investigating work-related discomfort and prompting early reporting. Subjects are shown a body map and asked to identify areas where discomfort has been experienced in the last: day, week and year. The extent to which the discomfort has stopped the subject from performing normal work and home activities is also recorded. A standardized form was developed by the Health and Safety Executive (HSE) in the UK (Dickinson et al., 1992). One of the changes introduced by HSE was to reduce the long term question to 3 months due to unreliability of recall. This HSE version of the NMQ was used in modified form by the Technical Advisory Group in the 1993-1996 Meat Industry Injury Prevention Project (Slappendel et al., 1996; Slappendel et al., 1996b), with particular care taken over the methods by which the questionnaire was administered (group discussion, one to one interview, postal survey etc). Method of administration has been found to be critical in generating sufficient response rates and hence reliable results when using the Nordic Questionnaire (Dickinson et al., 1992).

Frost et al. (1998) report on an exposure assessment questionnaire used to obtain information on present and former employment, actual employment status, tasks held at the slaughterhouse and self-reported ergonomics exposures.

3.15 Industry level initiatives

Sharing of ideas and knowledge between countries

Nossent et al. (1995) in their major review of the industries in Europe suggest that there is considerable experience across the 10 member countries of implementing interventions from plant from national level, the transfer of which should be encouraged and organized. ‘Synergies could be developed and possible duplications avoided’.

National level epidemiological and archival analysis

Moore et al. (2004) and Tappin et al. (2005) in New Zealand report a method that operates in between national level epidemiological data such as ACC figures, and individual plant study records collected by researchers. The Accident Register Survey approach involves compilation of entries contributed by a large sample of plants with the aim of developing ‘league tables’ of high risk Departments and tasks for MSD or other injury types. Lawson (1992) reports on an Australian initiative to share data with similar aims of identifying high risk targets for further on-site investigation.

Publication of Guidelines and worksheets on Acceptable Workload

Guidelines for acceptable workload are partly quantitative and based on biomechanical, physiological and psychophysical criteria that are concerned with high-amplitude exposures of moderate duration. In the case of qualitative guidelines, while reasonable confidence exists regarding the nature of risk factors, the exposure-effect relationship remain unknown (Westgaard, 2000).

In New Zealand, Guidelines and Worksheets have been available in various forms over time, OSH (1997) for example. The Ford (1993) study used the earlier Department of Labour (OSH) Manual Handling Guidelines of 1991 in his study of palletising at a North Island meat plant. While simplistic, the guidelines enabled plant staff to interpret basic principles of good practice in manual handling – such as avoiding handling below mid-thigh and above shoulder height.

3.16 Ergonomics Programmes and Participative Design exercises

The Ergonomics Programmes reported in the literature have broadly similar structures – analysing the problem, designing interventions and then evaluating the outcome and refining the system.

Identified weaknesses of the literature on ergonomics programmes are that: successes are more likely to be reported than failures, case studies are not controlled for other influences, and increased management attention to worker groups, and the role of ‘Hawthorne Effect’ is rarely discussed (NIOSH, 1994). The NIOSH study concludes however that, despite these weaknesses, the case Studies speak for themselves in demonstrating the value of worker contributions to positive hazard control accomplishments, and suggests that successful programmes include certain features. These are: management commitment, training of both managers and workers on the team, composition that reflects the full work system involved, information sharing between departments, working to specific goals, performance evaluation and feedback.

In Australia, Shaw and Blewett (2001) report a pilot study that looked at the role of participation at all levels in Continuous Improvement Programmes in Occupational Health and Safety (CIP OHS). The pilot involved plants in three States. They concluded that in plants where participative action was excluded from the exercise little improvement was achieved in the working environment and an increase in cynicism towards OHS professionals was noted amongst both workers and management. The evaluation suggested that ‘where manager-worker relations are less than cordial, a top-down approach to organisational change is not likely to succeed in the long term.’ Participative programmes, they suggest, can not only produce better working environments through joint problem-solving, but also improved industrial relations generally.

Loppinet & Aptel (1997) give four principles for successful ergonomics actions in a plant. They should be:

- participatory
- multidisciplinary
- global and systematic (it studies all aspects of the system)
- embedded in time (regular analysis and reorientation as needed)

Two examples of NIOSH-funded ergonomics programmes run at plants in the USA are reported Riley et al. (1994) and Schoenmarklin (1994). Riley et al. report significant measurable successes with most of the teams formed, Schoenmarklin reports more limited interventions actually implemented and the reasons for this are discussed. Organisational barriers to implementation are a prevalent feature of reports on ergonomics programmes.

The earliest reports of formalised worker participation in design in meat processing in New Zealand are from Hanara (1980, 1981). Pere Hanara, an industrial designer at the Meat Industry Research Institute of New Zealand (MIRINZ) developed a method which he called Committee Design. Under this approach, teams including subject experts from the floor jointly developed and trialed improvements to workstations. Inclusion of the workers was seen as critical. “There is always a better way..... and the people who actually work on those tasks are the best ones to find (it)”. A portable rig for taking anthropometric data was built and used by MIRINZ. The Committee Design approach is to develop a prototype and test and alter it until the workers involved agree that it has been optimised. The process is also reported to spread responsibility for the success of the changes.

Hanara emphasises that the signing off of a design developed in this way commits the management to actually build to those dimensions, and the workers to work with it without complaint once installed.

Stuckey, et al (1995) describe an Australian applied ergonomics training programme for abattoir boning room and slaughter board staff. The programme was said to present information in a manner “applicable to any setting while being sensitive to the work culture and learning requirements of the participants” and was described as successful in terms of acceptance by participants, increased efficiencies and safer work practices.

Moore & Garg (1997) produced a set of three papers that report on an exercise conducted over six years in a pork processing plant in the USA. Their evaluation showed that over that period crude incidence rates and lost-time incidence rates increased, but a shift from Lost-Time to Restricted Time was noted. The percentage of recordable disorders that were ergonomics-related stayed consistent but a progressive and consistent decrease in inflation adjusted Annual Workers Compensation costs was observed. Their interpretation of the findings were that increased awareness amongst staff had resulted in the increase in early reporting and early treatment of injuries. Savings were via reduced severity, or costs per case, rather than reduced incidence. The author notes that the study was limited by the lack of control groups (other plants without programmes) and the absence of a pre versus post-intervention comparison.

de Looze et al. (2001) discussed seven case studies aimed at reducing physical stress. Key factors for success were:

1. Direct worker participations and a strong commitment from the management team – key issues in participatory ergonomics (Noro & Imada, 1992).
2. A broad analysis of the occupational tasks and the potential health problems as a starting point.
3. Installation of a working or steering group at the beginning of the process consisting of all necessary disciplines.
4. Awareness of negative side effects that may occur – ie replacing a reduction of trunk flexion with an increased wrist loading.
5. Taking a stepwise approach to the project even though main risks and solutions may be obvious at first glance.

While the outcome of higher productivity and reduced physical stress was attractive for workers and management, higher productivity was found not always to be necessary to obtain success.

The (U.S.) OSHA Ergonomics Program (1999) states that: (1) There is a positive relationship between work-related musculoskeletal disorders and workplace risk factors, and (2) ergonomics programs and specific ergonomic interventions can reduce these injuries. The evidence includes: a 1997 General Accounting Office report of companies with ergonomics programs; and hundreds of published "success stories" from companies with ergonomics programs'. It is concluded that 'Ergonomics programs have demonstrated effectiveness in reducing risk, decreasing exposure and protecting workers against work-related MSD'.

4. Barriers to MSD interventions in meat processing

4.1 Old buildings

In Australia, it was noted by Waniganayake & Steele (1990) that older establishments often had inherent structural constraints which led to congestion, excessive use of platforms, poor housekeeping, increased manual handling, increased slip and trip hazards, and frequent stooping/twisting/reaching.

4.2 Commercial sensitivity

Studies in the New Zealand meat industry in the 1990s reported a disappointing lack of information sharing regarding Health and Safety. Tight profit margins do not engender openness on any matter that might provide a competitive advantage, and that has included ways to minimise losses through MSD. Competition between plants, even within the same company, had restricted the movement of good ideas on assessment and interventions (Slappendel et al., 1996; Caple & Hodgson (1992). Better transfer between companies and countries as suggested by Nossent et al. (1995) is therefore reliant on an easing of this sensitivity, so that Health and Safety are viewed collectively as an industry issue.

4.3 Daily tally system and work compression

Waniganayake & Steele (1990) identified that the traditional compression generated an expectation of shorter working days than the 8 hours accepted in most industries. Less experienced staff can struggle when the pace is set by the more senior workers. Plant staff who have their job made easier by an intervention, but are still able to ‘compress’ their work day, may well choose to convert this advantage into greater production output or shorter hours. The MSD incidence may not therefore change according to Slappendel et al. (1996a). They observed that those who had the ability to influence compression or increased tally to achieve greater pay were of higher shed seniority and worked at the ‘upstream’ end of the process. Those placed most at risk from increased workpace and reduced breaks were packers and trimmers downstream in the process who had little influence and low seniority.

4.4 Seniority and Pay Scales

The work systems used in New Zealand meats plants are based on chains of processing. A plant may have more than one chain per species, and as flow of stock changes during the year lines are closed down or started up. These work systems are referred to by Curtis (1992) as ‘exclusionary practices (that) have formed a central tenet of worksite organisation’ giving more experienced staff confidence of how quickly they will return after seasonal shutdowns, to which precise tasks and at what level of pay. They have also emerged partly through a need for the employers to have greater surety of workforce capability in an industry that lays off all processing staff for several weeks a year, offsetting the danger that insufficient skilled workers would return when the plant reopened. Curtis suggests that this is fundamentally different to countries such as Argentina where the plants are supplied more continuously by larger agri-businesses, rather than smaller independent farms as in New Zealand.

Seniority and pay scale differentials can make introducing changes to work patterns more difficult. For example, a logical task to include in a rotation pattern may be unacceptable within the Department, if it is on a different pay scale, or it does not match the seniority of the staff.

4.5 Skill shortage

Waniganayake & Steele (1990) in Australia noted that job rotation was limited by available expertise. In New Zealand, Slappendel et al. (1996) described the problem of employers asking well-trained people to work longer hours - rather than recruit more staff or draw from reserve pools where staff are likely to be less experienced and less trained.

4.6 Lack of ownership of interventions by the plant staff

In their case study of a New Zealand plant that brought in an external facilitator to set up an OOS programme, Leong & Greenslade (1997) noted the importance of overcoming resistance by supervisors and managers and securing their personal involvement. Staff at any level can be unconvinced of the presence of a problem and a need for change. This is referred to in the literature as a pre-contemplative state (Haslam, 2001) – they are yet to contemplate any need for remedial actions, as MSD risk factors, such as holding knives for long periods in gloved hands without returning them to the scabbard, may not be immediately evident. Moore & Tappin (1997) and Leong & Greenslade (1997) report success with the use of practical experiential sessions to move staff on to a more contemplative state. The use of simple tools such as biofeedback devices for example, allow individuals to experience the difficulties of consciously relaxing muscle groups sufficiently during unbroken work.

4.7 Insufficient time during design & build exercises

Meat plants generally attempt to conduct major building refits during the relatively short annual shutdown period of a few weeks. This gives little opportunity for the trialing of new structural arrangements to workplaces and workstations (Slappendel et al., 1996). The design work preceding this work is also often completed in haste, and with inadequate consultation with those on the floor (Hanara, 1981).

4.8 Hygiene Compliance

Hygiene concerns are reported to contribute to a conservative approach with innovations that might reduce MSD, but also need approval from inspectors (Slappendel et al., 1996). This limits solutions available for improving sole-surface traction and adjustability. The necessity to maintain product (and hence ambient) temperatures within certain boundaries in boning rooms determines maximum times for completing the boning, trimming and packing tasks. These regulations can therefore directly constrain interventions that moderate workload. Untested assumptions about cross-contamination between carcasses from glove use have also historically hindered objective attempts to reduce knife cuts in pre-inspection areas (Greenslade et al., 1998; Khela & Legg 1998). Waniganayake & Steele (1990) in Australia note that the requirement to keep meat for human consumption clear of the floor and platform edges results in excessive leaning into make cuts, especially when the animal is large. This is also the case in New Zealand.

4.9 Difficulties in evaluating interventions to show benefits

The absence of control cases and pre-intervention measures for comparative purposes in the longitudinal studies on plants reviewed weakens the studies (Moore & Garg, 1997) and makes it difficult to convince industry personnel of the merits on a purely financial basis.

References

- AMIEU, & MATFA. (1995). National guidelines for health and safety in the meat industry. Australian Meat Industry Employees Union and the Meat and Allied Trades Federation of Australia.
- Bongers, P. M., Winter, C. R., Kompier, M. A., & Hildebrandt, V. H. (1993). Psychosocial factors at work and musculoskeletal disease. *Scandinavian Journal of Work Environment and Health*, 19, 297-312.
- Brasington, C. F., & Hammonds, D. R. (1971). *Boning carcass beef on the rail: a feasibility study*: United States Department of Agriculture.
- Broberg, E. (1996). *Anmalda arbetssjukdomar i Norden 1990-1992 (Reported occupational diseases in the Nordic countries 1990-1992)*. Temanord: The Nordic Council of Ministers.
- Buckle, P. W., & Devereux, J. J. (2002). The nature of work-related neck and upper limb disorders. *Applied Ergonomics*, 33, 207-217.
- Caple, D. C. (1992). Musculoskeletal injury prevention - meat industry intervention study. In: *Unlocking Potential for the Future Productivity and Quality of Life: Proceedings of the Ergonomics Society of Australia (ESA) conference, Melbourne 1992*.
- Caple, D. C. (1994). *Noise control for abattoirs*. Unpublished report by David Caple Associates for the Meat Research Corporation, Sydney, NSW, Australia.
- Caple, D. C., & Hodgson, R. (1992). Meat processing industry - 100 micro ergonomic solutions. In: *Unlocking Potential for the Future Productivity and Quality of Life: Proceedings of the Ergonomics Society of Australia (ESA) conference 1992*. Melbourne.
- Chatigny, C., & Vezina, N. (1992). Analysis of knife sharpening in a pork abattoir (HSL translation from French). In: *Proceedings of 25th annual conference of the Human Factors Association of Canada.*, University of Quebec, Montreal.
- Christensen, H., Sogaard, K., Pilegaard, M. and Olsen Engineer, H. (2000). The importance of the work/rest pattern as a risk factor in repetitive monotonous work. *International Journal of Industrial Ergonomics* (25), 367 - 373.
- Christensen, H., & Larsen, J. (1995). Handgrip strength and forearm muscle activity during meat cutting. In: *PREMUS Book of Abstracts* (pp. 72 - 74). Montreal, Canada.
- Claudon, L. (2000). Ergonomic hand tool design: interview of users. In: *Proceedings of Ergonomics and Safety for Global Business Quality and Productivity conference 2000*.
- Claudon, L. (2006). Influence on grip of knife handle surface characteristics and wearing protective gloves. *Applied Ergonomics*, 37(6), 729-735.
- Claudon, L., & Marsot, J. (2006). Effect of knife sharpness on upper limb biomechanical stresses - a laboratory study. *International Journal of Industrial Ergonomics*, 36, 239-246.
- Cochrane, D. J., Riley, M.W. (1986b). The effects of handle shape and size on exerted forces. *Human Factors*, 28(3), 253-265.
- Cochrane, D. J., & Riley, M. W. (1986a). An evaluation of knife handle guarding. *Human Factors*, 28(3), 295-301.
- Conroy, C. (1989). Work-related injuries in the meatpacking industry. *Journal of Safety Research*, 20(2), 47-53.
- Curtis, B. (1992). The export meat industry. In: *Proceedings of the 5th conference: Labour, employment and work in New Zealand*, Wellington.
- Dababaneh, A., Swanson, N., & Shell, R. (2001). Impact of added rest breaks on the productivity and well being of workers. *Ergonomics*, 44(2), 164 - 174.

- deLooze, M., Urlings, I., Vink, P., van Rhijn, J., Miedema, M., Bronkhorst, R., et al. (2001). Towards successful physical stress reducing products: an evaluation of seven cases. *Applied Ergonomics*, 32(5), 525 - 534.
- Devereux, J., Rydstedt, L., Kelly, V., Weston, P., & Buckle, P. (2004). *The role of work stress and psychological factors in the development of musculoskeletal disorders: The stress and MSD study*. Prepared by Robens Centre for Health Ergonomics for the Health and Safety Executive, Research Report 273.
- Dowd, P. (2001). *Improving average knife sharpness in the New Zealand meat industry: progress summary of results from MIRINew Zealand Inc project*. Hamilton: MIRINew Zealand.
- Drewczynski, A., & Bertolini, R. (1995). Repetitive Motion Injuries: beefing up prevention. *Occupational Health and Safety Canada*, Sep/Oct 11(5), 137-142.
- Enander (1988). cited In: Ilmarinen, R., Tammela, E., and Korhonen, E. (1990). Design of functional work clothing for meat-cutters. *Applied Ergonomics*, 21(1), 2- 6.
- Falck, B., & Aarnio, P. (1983). Left-sided carpal tunnel syndrome in butchers. *Scandinavian Journal of Work, Environment & Health*, 9, 291 - 297.
- Fleming, S. L., Jansen, C. W., & Hasson, S. M. (1997). Effect of work glove and type of muscle action on grip fatigue. *Ergonomics*, 40(6), 601-612.
- Fogleman, M. T., Freivalds, A., & Goldberg, J. H. (1993). An ergonomic evaluation of knives for two poultry cutting tasks. *International Journal of Industrial Ergonomics*, 11, 257 - 265.
- Ford, D. (1993). *The elbow and knuckle heights of meat process workers*. Unpublished student assignment (DBA course). Massey University, Palmerston North, New Zealand.
- Ford, D. (1993). *Manual handling in the palletising area at AFFCO Feilding*. Unpublished student assignment (DBA course). Massey University, Palmerston North, New Zealand.
- Frost, P., Andersen, J.H. (1999). Shoulder impingement syndrome in relation to shoulder intensive work. *Journal of Occupational Environmental Medicine* (56), 494-498.
- Frost, P., Andersen, J. H., & Nielsen, V. K. (1998). Occurrence of carpal tunnel syndrome among slaughterhouse workers. *Scandinavian Journal of Work, Environment & Health*, 24(4), 285 - 292.
- Genaidy, A. M., Delgado, E., Bustos, T. (1995). Active microbreak effects on musculoskeletal comfort ratings in meatpacking plants. *Journal of Industrial Medicine*, (8), 375-379.
- Gorsche, R. J., Wiley, J.P., Renger, R.F., Brant, R.F., Gemer, T.Y., Sasyniuk, T.M. (1999). Prevalence and incidence of carpal tunnel syndrome in a meat packing plant. *Journal of Occupational Environmental Medicine*, (56), 417-422.
- Gorsche, R. J., Wiley, J. P., Renger, R. F., Brant, R. F., Gemer, T. Y., & Sasyniuk, T. M. (1998). Prevalence and incidence of stenosing flexor tenosynovitis (trigger finger) in a meat-packing plant. *Journal of Occupational Environmental Medicine*, 40(6), 556 - 560.
- Grant, K. A., & Habes, D. J. (1997 [req mass]). An Electromyographic Study of Strength and Upper Extremity Muscle Activity in Simulated Meat Cutting. *Applied Ergonomics*, 28(2), 129-137.
- Graves, R., Way, K., Riley, D., Lawton, C., & Morris, L. (2004). Development of risk filter and risk assessment worksheets for HSE guidance - 'Upper Limb Disorders in the Workplace'. *Applied Ergonomics*, 35, 475-484.
- Greenslade, E., Moore, D. J., & Tappin, D. C. (1998). *Meat Industry Injury Prevention Project - Case study six: Improving the personal equipment of meat workers*. Wellington: New Zealand Council of Trade Unions.

- Hanara, P. (1980). Productivity through design. *4Quarter*, 2.
- Hanara, P. (1981). Worker designers. *Designscape*, 134, 13-16.
- Haslam, R. A. (2001). Horses for courses - tailoring ergonomics to fit the client. In: *Proceedings of the 2001 New Zealand Ergonomics Society Conference, Rotorua*.
- Hsiang, S., McGorry, R., & Bezverkhny, I. (1997). The Use of Taguchi's Methods for the Evaluation of Industrial Knife Design. *Ergonomics*, 40(4), 476 - 490.
- Ilmarinen, R., Tammela, E., & Korhonen, E. (1990). Design of functional work clothing for meat-cutters. *Applied Ergonomics*, 21(1), 2- 6.
- Isolani, L., Bonfiglioli, R., Raffi, G. B., & Violante, F. S. (2002). Different case definitions to describe the prevalence of occupational carpal tunnel syndrome in meat industry workers. *International Archives of Occupational Environmental Health*, 75, 229 - 234.
- Johnson, J. E. (1998 [req mass]). Ergonomic Considerations in Development of a Power Tool for Cutting Meat. In S. Kumar (Ed.), *Advances in Occupational Ergonomics and Safety 2* (pp. 432 - 435). Amsterdam: IOS Press.
- Juul-Kristensen, B., Fallentin, N., Hansson, G.-A., Madeleine, P., Andersen, J. H., & Ekdahl, C. (2002). Physical workload during manual and mechanical deboning of poultry. *International Journal of Industrial Ergonomics*, (29), 107 - 115.
- Khela, N., & Legg, S. J. (1998). *The incidence of knife-induced hand injuries and the effect of glove usage on cross-contamination in pre-inspection slaughter areas in adult beef processing plants in New Zealand*. Research report for Meat New Zealand, (contract # 97FS/MU122: Milestone 5), Massey University.
- Kurppa, K., Viikari-Juntura, E., Kuosma, E., Huuskonen, M., & Kivi, P. (1991). Incidence of tenosynovitis and epicondylitis in a meat processing factory. *Scandinavian Journal of Work, Environment & Health*, (17), 32-37.
- Lawson, S. (1992 [req mass]). Reduction of Manual Handling Injuries in High Risk Industries. In: *Proceedings of 'Unlocking Potential for the Future Productivity and Quality of Life', 28th Annual Conference of the Ergonomics Society of Australia Inc, 2-4 December 1992.*, Melbourne, Australia.
- Leong, L. & Greenslade, E. (1997). *Meat Industry Injury Prevention Project - Case Study Four: OOS prevention in the workplace*. Wellington: New Zealand Council of Trade Unions.
- Li, G. and Buckle, P.W. (1999). Current techniques for assessing physical exposure to work-related musculoskeletal risks, with emphasis on posture-based methods. *Ergonomics*, 42(5), 674-695.
- Loppinet, M., & Aptel, M. (1997). *Musculoskeletal disorders in the meat industry* (translation from the French by Health and Safety Laboratories, UK). Nancy, France: INRS.
- Magnusson, M., Ortengren, R., Andersson, G. B. J., Petersen, I., & Sabel, B. (1987). An ergonomic study of work methods and physical disorders among professional butchers. *Applied Ergonomics*, 18(1), 43 - 50.
- Marklin, R. W., & Monroe, J. F. (1998). Quantitative biomechanical analysis of wrist motion in bone-trimming jobs in the meat packing industry. *Ergonomics*, 41(2), 227 - 237.
- Marsot, J., Claudon, L., & Jacqmin, M. (2007). Assessment of knife sharpness by means of a cutting force measuring system. *Applied Ergonomics*, 38(1), 83-89.
- McGorry, R. W. (2001). A system for the measurement of grip forces and applied moments during hand tool use. *Applied Ergonomics*, 32, 271-279.

- McGorry, R. W., Dempsey, P. G., & O'Brien, N. V. (2004). The Effect of Workstation and Task Variables on Forces Applied during Simulated Meat Cutting. *Ergonomics*, 47(15), 1640 - 1656.
- McGorry, R. W., Dowd, P., & Dempsey, P. G. (2005). The effect of blade finish and blade angle on forces used in meat cutting operations. *Applied Ergonomics*, 36, 71-77.
- Moore, D., & Tappin, D. (1997). *Meat Industry Injury Prevention Project - Case Study Five: ergonomics awareness training*. Wellington: New Zealand Council of Trade Unions.
- Moore, D., Tappin, T., & Vitalis, A. (2004). Accident register surveys: developing league tables of tasks linked to high incidences of musculoskeletal disorders. In: *Proceedings of the 12th Conference of the New Zealand Ergonomics Society, Taupo*. New Zealand.
- Moore, J. S., & Garg, A. (1997). Participatory ergonomics in a red meat packing plant. Part 1: Evidence of long term effectiveness. *American Industrial Hygiene Association Journal*, 58(2), 127-131.
- Mumford, C. (1996, Jan/Feb). OH&S training for meat processing workers. *Accident Prevention*, 43, 26-27.
- NIOSH, Centers for Disease Control and Prevention. Musculoskeletal Disorders and Workplace Factors. (1997). *A Critical Review of Epidemiologic Evidence for Work-Related Musculoskeletal Disorders of the Neck, Upper Extremity, and Low Back*. Edited by: Bernard, B. (1997), U.S. Department of Health and Human Services, National Institute for Occupational Safety and Health.
- NIOSH. (1994). *Participatory Ergonomic Interventions in Meatpacking Plants*. Edited by: Gjessing, C.C., Schoenborn, T.F. & Cohen, A. U.S. Department of Health and Human Services, National Institute for Occupational Safety and Health.
- Noro, K., & Imada, A. (1992). *Participatory Ergonomics*. London: Taylor and Francis.
- Nossent, S., de Groot, B., & Verschuren, R. (1995). *Working Conditions in the European Meat Processing Industry*. Dublin, Ireland: European Foundation for the Improvement of Living and Working Life.
- NZQA. (undated). *Unit No 2503: Sharpen and maintain hand knives in the meat processing industry*. Wellington: New Zealand Qualifications Authority.
- Occhipinti, E., Columbini, D., Bulgheroni, M., & Grieco, A. (1993). Evaluation of the strain in the upper limb muscles during different meat cutting tasks by means of vocational EMG. In: Marras, W.S., Karwowski, W., Smith, J.L. & Pacholski, L. (Eds.), *The ergonomics of manual work*. London: Taylor and Francis.
- OSH. (1997). *Muscle Minding: a guide for the prevention of OOS in the meat, poultry and fish processing industries*. Wellington: Occupational Health and Safety Service, Department of Labour.
- OSHA. (1999). *Ergonomics Programme. - 64:65768-66078 (proposed rule)*. US Department of Labour. Occupational Health and Safety Administration.
- Oxenburgh, M. (1991). *Increasing productivity and profit through Health & Safety*: CCH International.
- Piedrahita, H., Punnett, L., & Shahnavaz, H. (2004). Musculoskeletal symptoms in cold exposed and non-cold exposed workers. *International Journal of Industrial Ergonomics*, 34(4), 271 - 278.
- Rata, S. (1995). *Knife Handling in the meat industry*. Published by: Meat Industry Training Board, New Zealand Fishing Industry Training Council, ACC.
- Riley, D. (1998). *Musculoskeletal disorders in meat de-boning work: a review of the literature* (No. EWP/98/14). Sheffield UK: Health & Safety Laboratory.

- Riley, D. (2001). *Reducing the risks of musculoskeletal injury in meat boning work: Final report (b) for circulation to working group members*. (No. ERG/01/05(b)). Sheffield, UK: Health & Safety Laboratory.
- Riley, M. W., Cochrane, D. J., May, D. R., Schwoerer, C. E., & Stentz, T. L. (1994). *Co-operative agreement for the demonstration of an ergonomic intervention in the red meat packing industry at Farmland Foods Inc., Denison, Iowa. Final Report*. US Department of Commerce, National Technical Information Service.
- Roto, P., & Kivi, P. (1984). Prevalence of epicondylitis and tenosynovitis among meatcutters. *Scandinavian Journal of Work Environment and Health*, (10), 203 - 205.
- Schoenmarklin, R. W. (1994). *Demonstration of ergonomic intervention in the red meat packing industry; final report*. Milwaukee: Marquette University.
- Schoenmarklin, R. W., & Marras, W. S. (1990). A dynamic biomechanical model of the wrist joint. In: *Proceedings of the 34th Meeting of the Human Factor Society*. Pub: HFES, Santa Monica, USA.
- Shaw, A., & Blewett, V. (2001). Having a Say Makes It Work - Participative Ergonomics in the Meat Industry. In: *Proceedings of the 37th Annual Conference of the Ergonomics Society of Australia*, November 2001, Sydney, NSW, 27-30.
- Slappendel, C., Moore, D., & Tappin, D. (1996). Ergonomics in the meat processing industry. In: *Proceedings of the 7th conference of the New Zealand Ergonomics Society*, Wellington.
- Slappendel, C., Moore, D., & Tappin, D. (1996a). *Meat Industry Injury Prevention Project - Case Study Two: preventing injuries by reducing work compression*. Wellington: New Zealand Council of Trade Unions.
- Slappendel, C., Tappin, D., & Moore, D. (1996b). *Strains/sprains injuries in the meat industry: work organisation as a factor in their prevention*. Unpublished discussion paper.
- Slappendel, C and Wilson, B. (1992). Anthropometric estimates for New Zealand adults. *Ergonomics New Zealand* (New Zealand Ergonomics Society Newsletter), 7(3), 5-6.
- Standards Australia. (1992). *AS 2336 - 1992. Meat industry - hand held knives*: Standards Australia.
- Stuckey, R., Fox, J., & Yaxley, R. (1995). *Problem solving in applied ergonomics: a training programme for abattoir boners and slaughtermen*. Paper presented at the Asia Pacific Conference on Occupational Health and Safety, Brisbane, Australia.
- Szabo, R. L., Radwin, R. G., & Henderson, C. J. (1998 [req mass]). The Influence of Knife Sharpness on Poultry Processing Operator Exertions and the Effectiveness of Re-Sharpener. In: *Human-System Interaction: The Sky's No Limit - Proceedings of the Human Factors and Ergonomics Society 42nd Annual Meeting*, October 5-9, 1998., Chicago, Illinois.
- Tappin, D., Vitalis, T., Bentley, T., Ashby, L., Moore, D., Parker, R., et al. (2005). An Ergonomics Study of Musculoskeletal Disorders in Meat Processing in New Zealand. In: *Proceedings of the 3rd International Conference on Ergonomics and Safety for Global Business Quality and Productivity - Ergon-Axia 2005*, San Diego.
- Tappin, D., Moore, D., Ashby, L., Parker, R. (2006). Investigating MSD in the New Zealand Meat Processing and Seafood Processing Industries. In: *Proceedings of the 16th International Ergonomics Association World Congress on Ergonomics*, Maastricht, Netherlands.
- Temmyo, Y., & Sakai, K. (1985). *An ergonomic study on workload in a slaughterhouse*. Paper presented at the International Symposium on Ergonomics in Developing Countries 1985, Jakarta, Indonesia.

- Toulouse, G., Vezina, N., Lapointe, C., & Geoffrion, L. (1991 req mass). Ergonomic intervention in working conditions in prok slaughterhouses. In: *Proceedings of the 11th Congress of the International Ergonomics Association*, Paris 1991.
- Van der Doelen, J. A., & Barsky, S. J. (1990). Repetitive strain injury within the meat-processing industry. *Occupational Health in Ontario*, 11(4), 154 - 167.
- Van Eerd, D., Beaton, D., Cole, D., Lucas, J., Hogg-Johnson, S., Bombardier, C. (2003), Classification systems for upper-limb musculoskeletal disorder in workers: a review of the literature. *Journal of Clinical Epidemiology*, 56, 925-936.
- Viikari-Juntura, E., Kurppa, K., Kuosma, E., Huuskonen, M., Kuorinka, I., Ketola, R., et al. (1991). Prevalence of epicondylitis and elbow pain in the meat-processing industry. *Scandinavian Journal of Work, Environment & Health*, (17), 38 - 45.
- Wallersteiner, A., & Arnold, A. K. (1989). Ergonomic solutions to address the occupational health problems of the meat processing industry. In: *Proceedings of the Human Factors Association of Canada 22nd Annual Conference*, Toronto, Ontario.
- Waniganayake, A., & Steele, P. (1990). *Meat Industry Survey of Abattoirs*. Paper presented at the Ergonomic Design of Products for the Consumer conference, Adelaide.
- Westgaard, R. H. (2000). Work-related musculoskeletal complaints: some ergonomics challenges upon the start of a new century. *Applied Ergonomics*, 31(6), 569-580.
- Wood, G., Fisher, D.L., & Andres, R.O. (1997). Minimizing fatigue during repetitive jobs: optimal work-rest schedules. *Human Factors*, 39(1), 83-101.
- Yassi, A., Sprout, J., & Tate. (1996). Upper limb repetitive strain injuries in Manitoba. *American Journal of Industrial Medicine*, (30), 461 - 472.

Bibliography

- ACC. (1996). *Injury prevention in the red meat processing industry – an annotated bibliography*. ACC, New Zealand
- ACC, & Treasury. (1996). *Analysis of work-related injuries: meat processing industry*. Wellington: Accident Compensation Corporation.
- Anon. (1967). Meat freezing company's safety campaign. *Labour and Employment Gazette*, pp. 28-30.
- Anon. (undated pre 2006). *Walkers Midshire Foods Work-Related Upper Limb Disorders (W.R.U.L.D) Project - Butchery Techniques*: Walkers Midshire Foods (USA).
- Berne, S. (1995). Economics of ergonomics. *Prepared Foods*, August, 147.
- Bishu, R., & Muralidhar, A. (1999). Gloves. In: *The Occupational Ergonomics Handbook*: CRC Press.
- Bishu, R. R., Calkins, C., Lei, X., & al., e. (1996). Effect of Knife Type and Sharpness on Cutting Forces. In: Mital, A., Krueger, H., Kumar, S., Menozzi, M. & Fernandez, J. (Eds.), *Advances in Occupational Ergonomics and Safety I* (Vol. 1, pp. 479 - 483). Cincinnati, Ohio, USA: International Society for Occupational Ergonomics and Safety.
- Blewden, M., & Wyllie, A. (1997). *Council of Trade Unions Injury Prevention Programme: outcome evaluation report*. Auckland: Alcohol and Public Health Research Unit, University of Auckland.
- Blewden, M., & Wyllie, A. (1998). Outcome findings from a pilot injury prevention project in the meat industry. *Journal of Occupational Health and Safety - Australia & New Zealand*, 14(4), 401-408.
- Butcher, G. W., Gentry, S. C., & Wakeling, B. J. (1978). *The design of freezing works for the 1970s*. Paper presented at the 20th Meat Industry Research Conference, Hamilton, New Zealand.
- Cammock, P., & Inkson, K. (1988). The meat freezing industry in New Zealand. In E. Willis (Ed.), *Technology and the labour process* (pp. 68-80). Sydney: Allen and Unwin.
- Caple, D. C. (2003). The 45 syndrome: age and MSD incidence amongst meat workers. In: *Ergonomics in the Digital Age, Proceedings of the 15th Triennial Congress of the International Ergonomics Association and the 7th Joint Conference of the Ergonomics Society of Korea and the Japan Ergonomics Society*, August 24-29, 2003, Seoul, Korea.
- Caple, D. C., & Moody, H. (2001). Cut-resistant gloves in the meat industry. *Journal of Occupational Health and Safety - Australia & New Zealand*, 17(2), 153-162.
- Claudon, L. (1998). Evaluation of grip force using electromyograms in isometric isotonic conditions. *International Journal of Occupational Safety and Ergonomics*, 4(2), 169-184.
- Claudon, L. (2003). The effect of gloves on the friction between the hand and the handle of a handtool: an example of the knife in the meat industry. In: *Ergonomics in the Digital Age, Proceedings of the 15th Triennial Congress of the International Ergonomics Association and the 7th Joint Conference of the Ergonomics Society of Korea and the Japan Ergonomics Society*, August 24-29, 2003, Seoul, Korea.
- Clayton. (1996). *Ergonomic success in the meat industry*. Edison, N.J., USA: Clayton Environmental Consultants.
- Coutarel, F., Daniellou, F. & Dugue, B. (2003). Examining Work Organization in Relation to Margins of Manoeuvre in Design and in Operation - is rotation a solution to MSD? Original Language: French. *PISTES*, 5(2), 24-.

- Cryer, C. & Ryan, B. (1992). Research and prevention projects aimed at work-related injury in New Zealand. *Australian and New Zealand Journal of Occupational Health and Safety*, 8(4), 309-316.
- Davis, M. (1997). Repetitive strains still plague European meat industry. *Safety and Health*, June, 78-81.
- Dickinson, C. E., Campion, K., Foster, A.F., Newman, S.J., O'Rourke, A.M.T. & Thomas, P. G. (1992). Questionnaire development: an examination of the Nordic Musculoskeletal questionnaire. *Applied Ergonomics*, 23(3);197-201.
- Dickinson, C.E., (1994) *Musculoskeletal symptoms reporting: A review of HSE surveys using the Nordic Musculoskeletal Questionnaire*. HSE Internal Report.
- Endander, A., Ljunsberg, A.-S., & Holmer, I. (1979). Effects of work in cold stores on man. *Scandinavian Journal of Work Environmental Health*, 5, 195--201.
- Farlow, D. W. (1990). *Recent overseas research into plant safety and productivity*. Paper presented at the 26th Meat Industry Research Conference, Hamilton, New Zealand.
- Hagberg, M., & Wegman, D. H. (1987). Prevalence rates and odds ratios of shoulder - neck diseases in different occupational groups. *British Journal of Industrial Medicine*, (44), 602 - 610.
- Hanara, P., & Allpress, L. J. (1978). *Plant Layout*. Paper presented at the 20th Meat Industry Research Conference, Hamilton, New Zealand.
- Hansen, J. (1993 not in review). OSHA regulation of ergonomic health. *Journal of Occupational Medicine*, 35(1), 42-46.
- Higgs, P., Young, V., Seaton, M., Edwards, D., & Feely, C. (1992). Upper extremity impairment in workers performing repetitive tasks. *Plastic and Reconstructive Surgery*, 90(4), 614-620.
- Holmboe, K. (1995). Daily Weight Lifted during Meat Cutting as a Risk Factor for Musculoskeletal Disorders. In: *Proceedings of the 2nd International Scientific Conference on Prevention of Work-Related Musculoskeletal Disorders, PREMUS 95*, September 24-28, 1995,, Montreal, Canada.
- Houlden, E. (1963). *Boning department tables*. Paper presented at the 5th Meat Industry Research Conference, Hamilton.
- Human Synergistics. (1984). *Development of safety skills in the New Zealand meat industry*. Wellington, New Zealand: Human Synergistics.
- Inkson, K., & Cammock, P. (1984). Labour process theory and the chain system in the New Zealand meatworks. *New Zealand Journal of Industrial Relations*, 9, 149-160.
- Jorgensen, M. (1990). Automation in the Danish meat industry - a case study on social shaping of technology. In: Karwowski, W. & Rahimi, M. (Eds.), *Ergonomics of Hybrid Automated Systems II*: Elsevier.
- Jorgensen, M., Riley, M. W., Cochrane, D., & Bishu, R. (1989). Maximum forces in simulated meat cutting tasks. In: *Proceedings of the Human Factors Society 33rd Annual Meeting*, October 16-20, 1989, Denver, Colorado.
- Kilbom, A. (1994). Repetitive work of the upper extremity: Part 1 - Guidelines for the practitioner. *International Journal of Industrial Ergonomics*, 14, 51-57.
- Kim, J., Stuart-Buttle, C., & Marras, W. S. (1994). The effects of mats on back and leg fatigue. *Applied Ergonomics*, 25(1), 29-34.
- Kong, Y.-K. & Freivalds, A. (2003). Evaluation of meat hook handles. *International Journal of Industrial Ergonomics*, 32, 13-23.

- Longdill, G. (1990). *Safety and machine development*. Paper presented at the 26th Meat Industry Research Conference, Hamilton, New Zealand.
- Macfarlane, D. (1990). *Safety - the Australian experience*. Paper presented at the 26th Meat Industry Research Conference, Hamilton, New Zealand.
- Magnusson, M. & Ortengren, R. (1987). Investigation of optimal table height and surface angle in meatcutting. *Applied Ergonomics*, 18(2), 146-152.
- Malchaire, J., Cock, N. & Vergracht, S. (2001). Review of the factors associated with musculoskeletal problems in epidemiological studies. *International Archives of Occupational and Environmental Health*, 74(2), 79-90.
- Marras, W. S., Granata, K., Davis, K., Allread, G., & Jorgensen, M. (1996). The effects of box weight, size and handle coupling on spine loading during de-palletising operations. In: *Proceedings of the Human Factors and Ergonomics Society 40th Annual Meeting*. HFES, Santa Monica, USA.
- McGorry, R. W., Dempsey, P. G., & Casey, J. S. (2004). The Effect of Force Distribution and Magnitude at the Hand-Tool Interface on the Accuracy of Grip Force Estimates. *Journal of Occupational Rehabilitation*, 14(4), 255-266.
- McGorry, R. W., Dowd, P. C., & Dempsey, P. G. (2005). A technique for field measurement of knife sharpness. *Applied Ergonomics*, 36, 635-640.
- Mills, R. A. (1993). *Beef and sheep operations, the future in New Zealand*. Paper presented at the Australian Meat Industry Research Conference, Gold Coast.
- Moore, J. S., & Garg, A. (1996). Use of participatory ergonomics teams to address musculoskeletal hazards in the red meat packing industry. *American Journal of Industrial Medicine*, 29(4), 402-408.
- Moore, J. S., & Garg, A. (1997). Participatory ergonomics in a red meat packing plant .Part 2. Case studies. *American Industrial Hygiene Association Journal*, 58(7), 498-508.
- Moore, J. S., & Garg, A. (1998). The effectiveness of participatory ergonomics in the red meat packing industry - Evaluation of a corporation. *International Journal of Industrial Ergonomics*, 21(1), 47-58.
- Nemec, K. (1992). *Literature review on injuries to meat industry workers: ACC*.
- NOHSC. (1990). *Code of Practice for Manual Handling*. National Occupational Health and Safety Commission (NOHSC).
- OSHA. (1991). *Ergonomics Program Management Guidelines for Meat Packing Plants*. Reprinted 1993: U.S. Department of Labour, Occupational Safety and Health Administration.
- Shackel, B., Beevis, D., & Anderson, D. M. (1967). Ergonomics in Automation of Meat Handling in London Docks. *Ergonomics*, 10(2), 251-&.
- Slappendel, C., Moore, D., & Tappin, D. (1996). *Meat Industry Injury Prevention Project - Case Study One: problem-solving teams*. Wellington: New Zealand Council of Trade Unions.
- Slappendel, C., Moore, D. J., & Tappin, D. C. (1996). *Meat Industry Injury Prevention Project - Case Study Three: finding better ways to measure plant safety*. Wellington: New Zealand Council of Trade Unions.
- Smith, M. J. (1994). A Case Study of a Participatory Ergonomics and Safety Program in a Meat Processing Plant. In: *Proceedings of the 12th Triennial Congress of the International Ergonomics Association, Toronto, Canada, August 15-19, 1994*.
- Snook, S. & Ciriello, V. (1991). The design of manual handling tasks: revised tables of maximum acceptable weights and forces. *Ergonomics*, 34(9), 1197-1213.

- Tappin, D., Vitalis, A. & Bentley, T. (2006). Adopting an industry-wide participative approach in facilitating MSD intervention implementation. In: *Proceedings of the 16th International Ergonomics Association World Congress on Ergonomics, Maastricht*.
- Theberge, N., GraNew Zealandow, K., Cole, D. & Laing, A. (2006). Negotiating participation: Understanding the "how" in an ergonomic change team. *Applied Ergonomics*, 37(2), 239-248.
- Viikari-Juntura, E. R. A. (1997). The scientific basis for making guidelines and standards to prevent work-related musculoskeletal disorders. *Ergonomics*, 40(10), 1097-1117.
- Vogel, K., & Hagg, G. M. (2003). TALE and Other Video-Techniques for Teaching and Evaluating Ergonomics in the Red Meat Industry. In: *Ergonomics in the Digital Age - Proceedings of the XVth Triennial Congress of the International Ergonomics Association and the 7th Joint Conference of the Ergonomics Society of Korea and the Japan Ergonomics Society, Seoul, Korea, August 24-29, 2003.*, Seoul, Korea.
- Worrell, G. A., Hilton, C. A., & Jackson, C. G. R. (1998). Female and Male Grip Strength Adaptation to Repetitive Work. In: Kumar, S. (Ed.), *Advances in Occupational Ergonomics and Safety 2* (pp. 382 - 385). Amsterdam: IOS Press.