

Effective Occupational Health Interventions in Agriculture

An International Literature Review of Primary Interventions Designed to Reduce Injury and Disease in Agriculture

**Rebecca Lilley
Colin Cryer
Kirsten Lovelock
Peter Davison**

Injury Prevention Research Unit

David McBride

Department of Preventive and Social Medicine

Stephan Milosavljevic

School of Physiotherapy

Kate Morgaine

Faculty of Dentistry

University of Otago

P O Box 913

Dunedin

New Zealand

May 2009

Table of Contents

Table of Contents	2
Executive Summary.....	5
Introduction	10
Previous Reviews	10
Methods	13
Search strategies	13
Inclusion criteria.....	13
Selection of eligible studies.....	14
Quality assessment	14
Results	15
Results of literature searches	15
Results of literature review.....	25
Educational Interventions	25
Children	25
Adults	32
Engineering and Design Interventions	38
Ergonomic Interventions	38
Personal Protective Equipment (PPE) Interventions.....	44
Health Screening.....	45
Other Interventions.....	48
Multi-faceted Interventions	49
Pooled results.....	53
Discussion.....	54
Issues to arise from the literature.....	59
Overall judgement of the evidence.....	61
Conclusion.....	62
Recommendations	64
References	66

List of Figures

Figure I: Overview of the literature search and review strategy	15
---	----

List of Tables

Table I: Summary table of intervention studies.....	16
Table II: Characteristics of studies evaluating the effectiveness of interventions to reduce child injuries on farms	29
Table III: Characteristics of studies evaluating the effectiveness of interventions to reduce adult injuries on farms	35
Table IV: Characteristics of studies evaluating the effectiveness of engineering and ergonomic interventions	41
Table V: Characteristics of studies evaluating the effectiveness of PPE and health screening interventions.	46
Table VI: Characteristics of studies evaluating the effectiveness of multi faceted interventional programs.....	51
Table VII: Pooled evidence of the effectiveness of educational interventions.	53

Acknowledgements

This study was funded and supported by the Occupational Health and Safety Joint Research Portfolio, a joint initiative in Occupational Health and Safety research, funded by the Accident Compensation Corporation (ACC), Department of Labour (DoL) and the Health Research Council of New Zealand (HRC). Dr Rebecca Lilley was additionally supported by a post-doctoral fellowship from ACC and HRC. The views and/or conclusions expressed in this report are those of the research team and may not reflect those of the funders.

The authors would like to thank Dr Lesley Day, Monash University Accident Research Centre, Melbourne, Australia, who reviewed a scientific paper derived from this report.

Abbreviations

ACC	Accident Compensation Corporation
AgDARE	Agricultural Disability Awareness and Risk Education Model
ASHBMP	The Agricultural Safety and Health Best Management Practices Manual
CI	Confidence interval
LBP	Lower back pain
MSD	Musculo-skeletal disorder
NAGCAT	North American Guidelines for Childhood Agricultural Tasks
NIHL	Noise induced hearing loss
PPE	Personal protective equipment
PTO	Power take-off
QI	Quality index
RCT	Randomised controlled trial
ROPS	Roll over protective structures
RR	Relative risk

Executive Summary

Introduction

Farm-related injury and disease are major health and safety concerns in the Agricultural sector with this sector contributing disproportionately to poor work-related injury and ill health outcomes in New Zealand.

This report is the first part of a comprehensive stock-take to produce an up-to-date knowledge base from which the ACC, Department of Labour and other stakeholders will be able to develop, introduce or modify targeted interventions to reduce the rates of injury and other harm to members of the target agricultural population.

This report describes the systematic review of the efficacy of primary interventions from farming communities worldwide targeted directly at the farm to reduce exposure to known occupational hazards and to reduce poor injury and health outcomes in this community.

Methods

This report seeks to evaluate the body of evidence to emerge since the reviews of the efficacy of agricultural injury prevention interventions targeted at children by Hartling et al (2004) and agricultural injury prevention interventions targeted at adults by De Roo and Rautiainen (2000). The search criteria from these 2 previous reviews were replicated with some refinements. In total 10 electronic databases were searched for studies meeting the inclusion criteria. The main electronic search was supplemented by a hand search of specialist occupational health and safety, biomechanical, ergonomic and injury journals. Further search strategies were also used to find any updated publications for studies included in the 2 previous reviews.

The criteria for inclusion were:

- 1) the paper evaluated the efficacy of interventions to prevent injury in farmers, farm workers and their families, reporting at least one objectively quantified outcome (eg. injury rate, or an intermediary outcomes such as safety knowledge, or change in behaviour);
- 2) the interventions were targeted at adults or children only, or both adult and child populations on the farm;
- 3) the study design was either a before/after study (pre/post study), case-control, cohort, controlled trial or randomised controlled trial (RCT); and
- 4) studies were published after the relevant time periods covered in the existing reviews.

Abstracts of studies that appeared at face value to meet the criteria of this review were obtained and reviewed by two independent reviewers for inclusion. Full copies of papers meeting the abstract review criteria were obtained and reviewed in their entirety. The methodological quality of the eligible studies was assessed using a partially validated quality assessment tool [1].

Results

In total 33 abstracts met our inclusion criteria and were included in the full review. On the basis of type of interventions evaluated 15 involved an educational intervention, 3 were engineering interventions, 5 were ergonomic interventions, 2 involved personal protective

equipment (PPE) interventions, 2 involved health screening, 2 were financial/organisational interventions and 4 involved multi-faceted interventions.

Educational Interventions. Educational interventions were split into those targeting children on farms (n=8) and adults on farms (n=7).

Children. Educational interventions targeted at children on farms varied in focus from school based interventions, such as school lessons for children, to community-based interventions, such as community camps and safety guidelines to policy interventions such as legislated tractor training certification. The interventions were primarily targeted at the child, with the only exception being a set of child development specific guidelines which targeted farming parents as the main decision maker with regards to allocating childhood farming activities. Primarily the evaluations investigated changes in safety knowledge, attitudes and behaviours, with few investigating the impact of the intervention on injury or health outcomes.

There is mounting evidence, although mostly of moderate quality, that farm safety camps and school lessons targeted at school children display efficacy in terms of improving safety knowledge, attitudes and/or behaviours in the short term. There was little evidence of any subsequent reductions in injury by these interventions. The NAGCAT (North American Guidelines for Childhood Agricultural Tasks) was found to be effective at reducing injuries with moderate evidence provided by a single RCT trial. A legislated tractor certification training intervention was found to be poorly targeted resulting in no evidence of any reduction in childhood tractor-related injuries on highways.

Adults. Adult educational courses/sessions were targeted at farm workers primarily while media awareness programs, self-audit manual and supportive network group interventions were targeted at the farm operator as the key decision maker on the farm. The evaluation of adult educational interventions investigated a range of different outcomes including: changes in hazard exposure, PPE use, product awareness, safety knowledge, behaviours and/or activity.

There is mounting evidence that interventions using environmental review, such as a farm safety audit/review, can result in reductions in on-farm hazard scores but there is little evidence that these lead to any subsequent reduction in injury. Socially supportive mechanisms, such as small discussion groups may result in improvements in safety knowledge, attitudes and behaviours longer term but these interventions have not been subjected to rigorous evaluation nor have they investigated any impact upon rates of injury. Additionally there is limited evidence that pesticide handling and use educational sessions lead to changes in farmer safety perceptions and reduced pesticide exposure on the farm.

Engineering and Design Interventions. Most work on the effectiveness of ROPS (Roll Over Protective Structures) and compulsory legislation to fit a ROPS to all operational agricultural tractors to reduce tractor roll-over deaths has occurred prior to this review [2]. However two studies investigating aspects of implementing ROPS retrofitting or enhancements to the basis ROPS operation were identified. The collective evidence indicates that ROPS are an effective means of reducing tractor-related roll-over deaths with fully enclosed cabs potentially more effective than open ROPS structures and seatbelt use with open ROPS more effective than no seat-belt use. There is limited evidence that the use of financial incentives alone to improve voluntary ROPS retrofitting on older model tractors is effective. There is good evidence to indicate strong legislation making ROPS installation compulsory on all operational tractors can reduce, if not virtually eliminate, tractor related fatal injuries.

Ergonomic & PPE Interventions. The effectiveness of ergonomic interventions at reducing musculoskeletal biomechanical loadings, subsequently reducing the likelihood of a person developing gradual process musculoskeletal injuries, were identified for orchard harvesting, sheep shearing, calf weighing and dairy milking. All were single studies of moderate methodological quality providing weak evidence of the effectiveness of ergonomic interventions to reduce biomechanical stresses during high repetition tasks. Similarly few studies of poor to moderate quality were identified evaluating the effectiveness of certain pieces of PPE to reduce exposures to known farm hazards. Weak evidence was found from a single study that personal gas filters are effective at reducing respiratory inflammation symptoms due to swine dust exposure.

Health Screening and Other Interventions. Two studies were identified that used a health screening intervention to improve use of hazard reduction measures such as PPE use and no-farm hazard reductions. Poor evidence was found for health screening and targeted education at health fairs being an effective intervention to stimulate changes in health and safety behaviours on the farm. Two additional studies were identified: one a financial intervention and one an organisational intervention. There was limited evidence from one study that modifying patterns of work and rest may be feasible for reducing musculoskeletal pain in repetitive farm tasks. Limited evidence was found that insurance premium discounting may be effective at reducing injury claims with little evidence of any effect on actual rates of injury, as opposed to compensation claims for injury.

Multi-faceted Interventions. Multi-faceted interventions used a number of separate interventional approaches to attempt to reduce agricultural injuries. Of the four studies identified all included one or more educational components mostly in conjunction with another intervention. There was moderate evidence of an educational component combined with PPE provision or multiple educational components can improve the use of safety equipment on the farm. Evidence from this and previous reviews indicate that multi-faceted interventions, where combinations of educational and other interventional approaches such as PPE provision or self-audit, are a promising interventional approach to improve farm safety behaviours, attitudes and knowledge. The efficacy of multi-faceted interventions at reducing injuries are not entirely clear as some studies displayed reductions in injuries but failed to obtain statistical significant reductions. Potentially a multi-faceted intervention using self-audit as one component may be effective at improving farm safety behaviours and practices and subsequently reduce farm injury.

Overall findings. Two previous reviews on the effectiveness of interventions to reduce injuries in agriculture both concluded that there was insufficient evidence to recommend one particular interventional approach to reducing agricultural injuries in the farm community. This updated review confirms these previous conclusions and provides further evidence that there is no single intervention type that is able to address the high rate of injury in the agricultural sector. Further to this there is no evidence that there is no single intervention type that is able to address the multitude of occupational ill health concerns in the agricultural sector.

This report also identifies a number of issues to arise from the literature including:

- Poor targeting of prevention programs to the major agricultural injury or health concerns, or to high risk populations.
- The need to reach beyond educational interventions and consider other engineering/design, organisation and legislative solutions.
- A need to understand the barriers to implementing interventions to improve the likelihood of success.

- The poor use of established theories of change to underpin intervention design.

This report also identified a number of methodological issues to arise from the literature including:

- Little examination of injury outcomes by intervention evaluations.
- Improved use of more rigorous study designs but overall the quality of evidence is still limited.
- Applicability of the study findings to the NZ agricultural context when most interventions are designed and undertaken in Northern Europe and North America.

Recommendations

The studies identified by this and previous reviews do not provide strong evidence for the establishment of evidence-based interventions applicable to the agricultural industry in New Zealand but do however point to the direction that could be taken. The following recommendations are made on the basis of this review of the effectiveness of agricultural interventions to reduce poor health and safety outcomes on farms

General intervention considerations

1. *Address the key injury and poor health causes.* Interventions need to be designed to address the key exposure/hazards faced by the farming community. Targeted interventions have a greater likelihood of success. To implement this recommendation a solid scientific evidence base is essential to identify and to apply interventional strategy.
2. *Interventions to reach beyond educational interventions.* Interventional approaches other than educational approaches need to be considered to address the multitude of mechanical, physical, biological, chemical, musculoskeletal and psychosocial hazards faced by farmers within the farming environment. Encourage the consideration of alternative interventions (ie. engineering, design, regulatory, ergonomic, financial and organisational).
3. *Multi-faceted interventions.* The inability to address agricultural health and safety concerns with a single educational, engineering or regulatory interventional approach leads us to recommend the use of a multi-faceted interventional approach to address these concerns. Interventions should be truly multi-faceted, including combinations of relevant educational, engineering/design and regulatory interventional components, where applicable, to address the key agricultural health and safety concerns.
4. *Consideration of the barriers to implementation of interventions.* Intervention design needs to consider how to include those farmers resistant to safety improvement in farming. Programs were found to respond better to groups with poor health and safety conditions at baseline. Steps such as identifying high risk, more resistant farmers at initiation of the intervention and providing targeted interventions to these groups may improve the outcome of the intervention.
5. *Sustained support.* Interventional programs work better if sustained over time in a supportive environment (ie. support networks, follow-up contact, booster interventions, farmer empowerment). The potential for other promotional activities to build upon programs with sustained support should be considered (ie. take place during times of heightened farm health and safety activity, have the support of key

stakeholder groups). Interventions are more successful if programs can be delivered in a receptive environment.

6. *Novel farm health and safety interventional approaches and leadership.* All approaches reviewed have targeted the farmer or farm manager attempting to influence through the farmer as the key decision maker in the farming operation. There is a whole chain of people involved in agriculture who may potentially be used to influence agricultural health and safety (ie. financial and insurance groups, commodity groups, commodity purchasers). Alternative targets for intervention need also to be considered.
7. *Underpinning intervention with established models for change.* Few interventions use an established model for change to underpin the mechanism of how the intervention will introduce change in farmer behaviour, activities or knowledge and subsequently impact upon rates of injury. Use of an established model for change will increase the likelihood of success of the intervention.
8. *Pilot testing interventions in the New Zealand agricultural context.* Any future interventions targeted at the agricultural industry in New Zealand need to be piloted and evaluated for their effectiveness at reducing agricultural injury and disease in the New Zealand agricultural context (in NZ farmers and on NZ farms), before being implemented nationally.

Research Agenda Recommendations. A future path for the development of agricultural injury and disease interventions in New Zealand is outlined taking into consideration the upcoming outcomes of the research programme “Effective occupational health interventions in agriculture: key characteristics of their development and implementation in New Zealand”. It is proposed / recommended that:

- a) The findings related to promising agricultural health and safety interventions for use in New Zealand will be presented to key stakeholder for consideration on the completion of the “Effective occupational health interventions in agriculture: key characteristics of their development and implementation in New Zealand” project.
- b) A program of development of appropriate interventions to reduce the burden of agricultural injury and disease will be formulated, drawing upon established models for change, in conjunction with key stakeholders.
- c) Any proposed intervention should be evaluated in New Zealand for it’s efficacy in controlled trials.
- d) If found to be efficacious under controlled conditions, the proposed intervention should be tested and evaluated its effectiveness under “field” conditions.
- e) If the intervention effect is positive, only then would the intervention be implemented on a national basis.

Introduction

Agriculture is an important part of the New Zealand economy, contributing over 60% of our export earnings and employing 9% of the total New Zealand workforce.

Injury is recognised as a key occupational health and safety concern for the agricultural industry. In NZ the Agricultural industry contributes to the greatest proportion of work-related fatalities in the working population with a fatality rate in males of 21.2 deaths per 100,000 workers from 1985-1994, just over 4 times the “all industry rate” for New Zealand [3]. The number of deaths to male workers in the agricultural sector contributed to a quarter of all work-related fatalities in the workforce during this period [3]. Internationally, in similar market economies to New Zealand such as Australia and the United States, agricultural sector workers are consistently at higher risk of fatal work-related injury compared with the rest of the working population [4]. Similarly the risks for non-fatal injury and disability are also consistently higher for agricultural workers.

Occupational health concerns, such as Noise Induced Hearing Loss (NIHL), the health effects of pesticide exposures, suicide and musculoskeletal disorders are also of great concern in the agricultural industry. New Zealand studies have identified NIHL, low back pain, chemically associated illness, mental health and stress as some of the occupational health concerns of farmers [5-8].

Agricultural occupations are high risk and contribute disproportionately to ACC claims and associated costs. Additionally risks to families who live or visit a farm, as well as other visitors to the farm are also significant [9, 10]. Consequently, it is important to take stock of the size and nature of the problem, the risks and hazards that this population are exposed to, options for prevention, and barriers to, and critical factors relating to, implementation of effective methods.

This report is the first part of a stock-take providing an up-to-date knowledge base from which the ACC, DoL and other stakeholders will be able to develop, introduce or modify targeted interventions that will reduce the rates of injury and other harm to members of the target agricultural population. This report describes the systematic review of the efficacy of primary interventions targeted directly at the farming community to reduce exposure to known occupational hazards on the farm and to reduce poor injury and health outcomes. This report presents the most up to date review of primary farm-related health and safety interventions from farming communities worldwide.

Previous Reviews

Prior to undertaking the systematic review of the effectiveness of farm-related health and safety interventions two previous reviews were identified. These reviews have been used as the basis for the current systematic review.

The review by **Hartling et al., (2004)** summarises the effectiveness of interventions to prevent childhood agricultural injuries. This review concluded that educational intervention programmes increased knowledge in children with regards to farm safety but the effect on injury rates was unknown. Hartling et al., (2004) identified 23 controlled studies, of which

only 8 were from peer reviewed publications. The child farm safety educational interventions included: school-based programs (n=7); community-based programs (n=12); a farm-based program (n=1) and a set of developmentally specific guidelines for assigning agricultural tasks (n=3). The community safety initiatives included a farm safety theatre (n=1), day camp (n=2), tractor safety initiatives (n=5) and multifaceted interventions (n=4). Schools-based programs consistently showed positive results appearing to be effective at increasing short-term knowledge acquisition, especially when the program included participatory rather than passive activities. Safety day camps were also found to be effective at increasing short-term knowledge acquisition, with one study showing that knowledge was maintained at a 1-year follow-up assessment. Tractor training programs and community and farm-based interventions displayed mixed results. The multifaceted interventions, involving more than one interventional approach within an interventional program, displayed mixed results with respect to youth interventions. A comparison of a several agricultural interventions including a specific youth intervention reported the youth intervention to produce little change in farm hazard scores [11]. These results were dependent upon the initial baseline hazard scores of the farm with those farms with poor baseline hazard scores displaying the greatest improvement in farm hazard scores. A self-audit component of this intervention evaluation was found to be the most effective at reducing farm hazard scores in adults [11]. Little evidence of the efficacy of the NAGCAT¹ guidelines for reducing childhood farm injuries was found by Hartling et al., (2004) but evaluations of the dissemination strategies to encourage the uptake of the guidelines were reported. Provision of information outlining the scientific basis of the guidelines and personal farm visits by a safety expert improved the rate of uptake of the guidelines and, improved outcomes compared with a standard dissemination strategy.

There has also been a review that has summarised the effectiveness of interventions to prevent farm injuries in both adults and children on the farm (De Roo). **De Roo and Rautiainen (2000)** identified 11 farm educational programs and 5 multifaceted interventions that all included an environmental audit/review, a farm visit, or both. The farm safety education interventions identified included: safety fairs (n=2); day camps (n=2); certification programs (n=1); workshops and educational courses (n=7). The multifaceted interventions generally involved farm safety audits, followed by environmental or equipment changes and / or safety education. Although many of the farm safety education programs reported positive results in terms of changes in farm safety knowledge, awareness and behaviours the evidence for the effectiveness of education programs in reducing injury was weak due to the use of inadequate study designs. The strongest evidence of a reduction in injury rates for an educational program was reported in reindeer herders in Finland using a pre/post study design. The multifaceted interventions provided greater evidence of efficacy in reducing injury risk with stronger evaluation designs used but all evaluations failed to achieve statistical significance. It was difficult to determine from the studies reviewed what components of the intervention were the most successful at reducing injuries. The review concludes that multi-faceted interventions involving a self-guided farm “walkabout” with checklists and educational booklets to identify and evaluate farm hazards was useful in helping some farm families recognise and modify environmental hazards, even without expert guidance.

Both the above reviews concluded that while some educational initiatives are effective at improving farm safety knowledge, attitudes and behaviours, that educational interventions by themselves are not efficient enough to significantly reduce farm-related injuries. The methodological quality of the papers reviewed was weak; they did not use the more rigorous study designs, or were of low power. The previous lack of rigorous study designs has been an

¹ North American Guidelines for Childhood Agricultural Tasks

impediment to the progression of knowledge regarding the most effective means of reducing agricultural injuries. This review seeks to evaluate the body of evidence to emerge since the review of Hartling et al. (2004) and De Roo and Rautiainen (2000).

Methods

Search strategies

Search strategies were obtained from the previous literature reviews of De Roo and Rautinian (2000) [12] and Hartling et al., (2004) [13]. These search strategies were replicated with some refinements.

We searched 10 electronic literature databases from January 2002 to May 2007 for intervention studies relevant to children and January 1999 to May 2007 for interventions studies relevant to adults (Agricola, CINAHL, Embase, ERIC, ISI Web of Science, Medline, NIOSHTIC-2, PsycINFO, SafetyLit, AMED).

The indexes of specialist journals were hand searched from May 2007 to January 2000 in the disciplines of:

- 1) agricultural health and safety (Journal of Agricultural Safety and Health, Journal of Rural Health, Australian Journal of Rural Health, Journal of Agromedicine);
- 2) occupational health and safety (American Journal of Industrial Medicine, Occupational and Environmental Medicine, Scandinavian Journal of Work and Environment);
- 3) applied ergonomic and biomechanical research (Applied Ergonomics, Ergonomics, Journal of Biomechanics); and
- 4) injury epidemiology (Injury Prevention).

Further searches strategies included searching for any updates or more recent publications from the studies included in either the Hartling et al., (2004), or De Roo and Rautiainen (2000) reviews by searching all the named literature databases:

- 1) by the published project name for further publications from these studies;
- 2) for papers citing these original studies using the ISI Web of Knowledge; and
- 3) for any further author publications since original publication.

An additional search was also carried out using the ISI Web of Knowledge for all references citing the key reviews of Hartling et al., (2004), or DeRoo and Rautiainen (2000).

Inclusion criteria

The following inclusion criteria were set:

- 1) The paper evaluated the efficacy of interventions to prevent injury in farmers, farm workers and their families, reporting at least one objectively quantified outcome (eg. injury rate, or an intermediary outcomes such as safety knowledge, change in behaviour, uptake of intervention etc).
- 2) Interventions were targeted at adults or children only, or both adult and child populations on the farm.
- 3) Study design was either a before/after study (pre/post test), case-control, cohort, controlled trial or randomised controlled trial.
- 4) Studies were published after the relevant time periods covered in the existing reviews (in children were published as scientific papers after 2002 and studies in adults published as scientific papers after 1998).

These criteria meant that papers that were descriptive studies or descriptions of interventions, without an evaluation, were excluded. Further exclusions included conference proceedings, reviews, opinion or commentary papers, and qualitative and process evaluations.

Selection of eligible studies

A reviewer assessed the eligibility of titles and abstracts of studies identified through searches. Abstracts of studies that appeared at face value to meet the criteria of this review were obtained and reviewed by two independent reviewers (R.L. & C.C.) for inclusion. Any discrepancies in assessment were resolved at a meeting of reviewers.

Once the set of abstracts of inclusion was decided upon a final review of references included in these papers was undertaken to ensure further relevant papers were not missed.

Quality assessment

Full copies of papers meeting the abstract review inclusion criteria were obtained and reviewed in their entirety.

The methodological quality of the eligible studies was assessed using the partially validated checklist of data quality developed by Downs and Black [1]. The tool creates a profile of the methodological quality of a paper, assessing reporting, external and internal validity (bias and confounding) and power, with a Quality Index (QI) created. The maximum value of the QI is 29. A QI score of >19 considered high, 11 to 19 moderate and <11 considered to be of poor methodological quality. Study quality was assessed by one reviewer (R.L.).

A meta-analysis was not attempted due to differences in study design, types of interventions, target populations and outcome measures.

Results

Results of literature searches

Both the childhood and adult literature review search strategies yielded over 6,000 papers from each of the initial searches undertaken. From these 113 were selected for abstract review and after in-depth abstract review 35 were considered to have met the inclusion criteria and were appropriate for full review (Figure I). A final check of the abstract revealed 3 abstracts were already included in the review of Hartling et al., (2003) and these abstracts were subsequently removed leaving 33 abstracts meeting our inclusion criteria and appropriate for full review.

On the basis of type of intervention evaluated 15 involved an educational intervention, 3 were engineering interventions, 5 were ergonomic interventions, 2 involved personal protective equipment (PPE) interventions, 2 involved health screening, 2 were financial or organisational interventions, and 4 involved multi-faceted interventions. A summary table of the identified studies is presented in Table I.

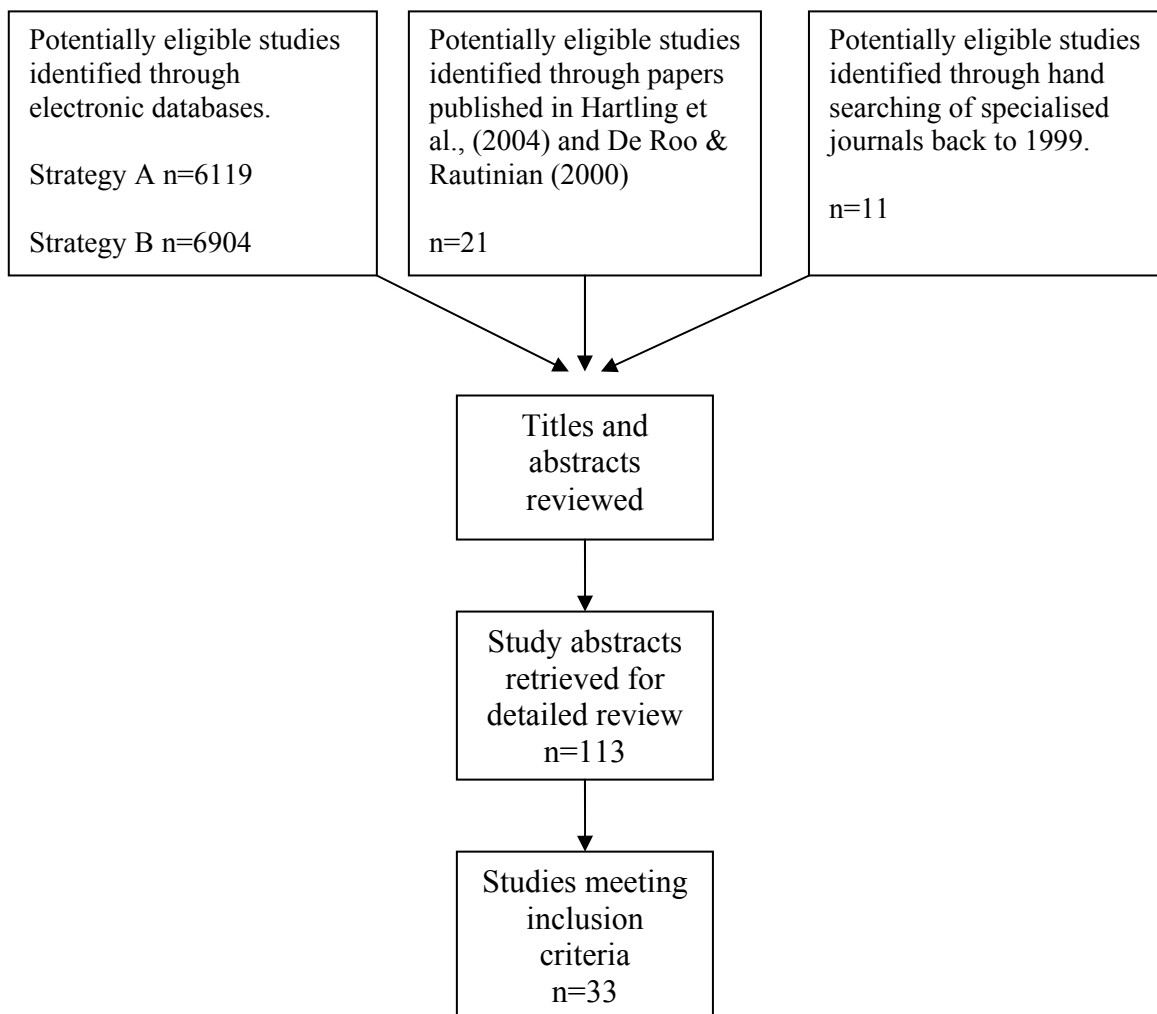


Figure I: Overview of the literature search and review strategy

Key: Strategy A – Updating Hartling et al., (2004) review search strategy, limited to papers published after 2002; Strategy B – Updating De Roo and Rautianen (2000) review search strategy, limited to papers published after 1999.

Table I: Summary table of intervention studies

Author Reference #	Design Design type Control type Subjects Outcome	Intervention Type	Measures	Findings	Quality of Evidence Quality score Quality rating
Educational interventions (education, training, guidelines) - Children					
Gadomski, et al., 2006 [14]	Experimental randomised control trial. Yes (no intervention). 931 farms. Injury.	Enhanced dissemination of voluntary guidelines (NAGCAT) for assignment of agricultural tasks to children. Enhancement included: Farm visit and educator review of guidelines. Booster reminders – post card and calendar.	Self-reported injuries resulting in at least 4 hours restricted activity. Time to injury. Violation of NAGCAT guidelines.	No differences in injury severity or incidence. Half of injuries reported not preventable under guidelines. Of those preventable reductions in injury densities with guidelines but ns. Significant increase in time to injury with guidelines. Significant changes to safety behaviour with child work assignment.	25 High
Kidd et al., 2003 [15]	Quasi -experimental controlled trial with cross-over of interventions. Yes (no intervention). 21 schools, 790 9 th & 10 th grade students. Safety behaviour/attitude.	Delivery of the AgDARE curriculum consisting of physical and narrative simulation exercises to high school agriculture classes.	Self-reported: Farm safety attitude instrument (FSA). Stages of change test (SOC). Observed: Work behaviour.	Significantly increased scores for contemplation and action stages in intervention groups. The majority of children visited on farms had made safety behaviour changes.	14 Moderate
Lee et al., 2004 [16]	Experimental randomised controlled trial. Yes (no intervention). 123 FFA chapters, 3081 students. Injury & safety behaviour/attitudes.	Delivery of a standard and enhanced partners program to chapters. The enhanced program included expert support & free PPE supplies on top of standard educational resources & training.	Self reported: Safety attitude, knowledge & behaviour. Injury experience in last 3 months.	No substantive effect of intervention on participants' self-reported knowledge, attitudes, activities, leadership, community participation or injury.	24 High

Author	Design Design type Control type Subjects Outcome	Intervention Type	Measures	Findings	Quality of Evidence Quality score Quality rating
Liller & Pintado 2005 [17]	Non-experimental pre-post test (staggered). No (subjects own controls). 2 migrant schools (66 students pre/post test & 91 post test only). Safety knowledge/behaviour.	Delivery of the Kids Count lesson on farm injury prevention to children aged 9-11 yrs. Lesson 45 minutes in length and delivered in English and Spanish.	Self-reported: Safety knowledge score Parental farm safety behaviour survey	Significantly increased mean safety knowledge scores after lesson. Parents reported improvements in safety behaviours after lesson.	17 Moderate
Marlenga et al., 2006 [18]	Quasi-experimental interrupted time series data. No (control time periods). 146 tractor crashes (children > 16 years). Tractor traffic crashes.	State legislation introduced to reduce tractor crashes involving youth operators. Legislation stipulates youths >16 years of age must complete a tractor certification course before operating a tractor on a highway.	Number of traffic crashes obtained from motor vehicle accident reports	No significant change in the number of youth crashes on highways. No reduction in proportion of youth at fault crashes nor type or number of circumstances attributed to youth.	Not assessed
McCallum et al., 2005 [19]	Non-experimental pre-post test. No (subjects as own control). 1780 students aged 8-13 yrs. Safety knowledge.	Attended a Progressive Farmer Farm Safety Day Camp.	Self-reported: Safety related knowledge Safety related behaviour ATV safety gear risk scale	Significant moderate increases in farm safety knowledge & safety behaviour correct answers were obtained. Moderate gains in knowledge, safety behaviour & ATV safety gear risk per child.	16 Moderate
Reed et al., 2003 [20]	Quasi-experimental pre-post study. No (subjects as own controls) 5 schools (29 students). Safety behaviour changes.	Educational farm safety lesson AgDARE, with simulation-exercise modules, based upon Transtheoretical Model of Change.	Observed: Behavioural changes Self-reported: Changes to behaviour	Improvements in work and safety behaviours were observed post intervention. No statistical testing was undertaken.	16 Moderate

Author	Design Design type Control type Subjects Outcome	Intervention Type	Measures	Findings	Quality of Evidence Quality score Quality rating
Reed & Kidd 2004 [21] (See also Kidd & Reed 2003 above)	Quasi - experimental pre/post trial with cross-over interventions with control group. Yes (no intervention). 21 schools (14 intervention, 7 control). Safety knowledge.	Educational farm safety lesson AgDARE, with simulation-exercise modules, based upon Transtheoretical Model of Change.	Self-reported: Farm safety attitude instrument. States of change instrument.	Significant improvements in farm safety attitude and farm safety behaviour with intervention. Significant improvement in the contemplation and action subscales. Same results as Reed and Kidd (2003) above.	13 Moderate
Educational interventions (education, training, guidelines) - Adults					
Chapman et al., 2004 [22]	Non experimental pre-post study with different samples at base and follow-up with a non-randomised control. Yes (strawberry growers, no intervention). Vegetable growers (103 base /71 follow-up). Awareness & adoption.	A media & public event awareness campaign for adoption of 2 production practices that aid handling, reducing exposure to musculo-skeletal hazards	Grower media exposure to information. Awareness, adoption and perception of mesh bags & standard containers.	Increased reports of exposure to print media. Significantly increased adoption of standard containers. Increases in awareness not significant. No significant increase in intention to adopt practices.	19 Moderate
Chapman et al., 2003 [23]	Non-experimental design pre-post study - different samples at base and follow-up. No. Dairy Farmers (421 baseline /426 follow up). Awareness & adoption.	A media & public event awareness campaign for adoption of 3 dairy production practices that reduce exposure to certain farm hazards.	Awareness of production practices: barn lights, calf feed mixing site and bag silos.	Increased reports of exposure to information from public events, private consultants, other farmers, and print media. Significant declines in unawareness of barn lights & feed mixing sites. Increased adoption of barn lights but ns.	19 Moderate
Heikkonen & Laouhevaara 2003 [24]	Experimental pre-post cohort with non-randomised control. Yes (farm walk through run by occupational health practitioner). 70 dairy farmers. Hazard reduction.	Small group farm safety walk through where farmers were empowered to direct the farm safety walk through them selves.	Observed: Changes made per farm post intervention	Significantly more changes made to intervention farms after empowered farm walk through.	18 Moderate

Author	Design Design type Control type Subjects Outcome	Intervention Type	Measures	Findings	Quality of Evidence Quality score Quality rating
Legault & Murphy 2000 [25]	Quasi-experimental pre-post prospective cohort. Yes (fact sheets and baseline hazard audit only). 150 farms. Hazard reduction.	Use of an audit manual (ASHBMP manual) plus expert hazard audit feedback. Other intervention groups: expert hazard audit feedback only or manual only.	Professional farm audits	Those receiving manual had significant reduction in hazards. Greatest reduction in hazard levels obtained with manual only rather than in combination with hazard audit results.	20 High
Perry & Layde 2003 [26]	Experimental randomised controlled trial. Yes (No intervention). 400 dairy farmers pesticide certified. PPE use and exposure reduction.	Three hour educational sessions covering: Cancer knowledge. Simulation of pesticide exposure. Feedback on reported exposure and PPE use. Cognitive behavioural strategies.	Self-reported: PPE use Dermal exposure	Educational intervention significantly reduced total pesticide use. Significant improvements on use of gloves and PPE during last application. No significant improvements in full PPE compliance or reducing dermal exposure.	26 High
Stave et al., 2007 [27]	Quasi experimental pre-post trial. Yes (basic support meetings with no expert input). 88 farmers. Hazard reduction & safety behaviour.	Farm safety program using two structured discussion interventions: 1) support meetings with additional incident diary analysing upstream causes. 2) Basic support with incident diary and educational information delivered.	Self-reported: Risk perception, manageability, & acceptance Work stress Safety activity & measures	Overall combined intervention significantly improved work safety measures on farm 14%. Greatest single improvement in work safety measures 46% by group receiving incident diary only but group started from lower baseline levels. No increase in risk perception of manageability after intervention.	17 Moderate
Vela Acosta et al., 2005 [28]	Quasi-experimental pre-post study with control group. Yes (no intervention). 152 farm workers. Safety knowledge.	Bilingual pesticide reduction program involving education on source of pesticide, toxicity, & absorption.	Self-reported: Pesticide knowledge Safety risk perception Health locus of control	Significant increases in pesticide knowledge & safety risk perception. Workers with an external health locus of control were less likely to adopt safety behaviours.	16 Moderate

Author	Design Design type Control type Subjects Outcome	Intervention Type	Measures	Findings	Quality of Evidence Quality score Quality rating
PPE					
Palmberg et al., 2004 [29]	Experimental randomised controlled trial Yes (no intervention mask). 22 previously non-exposed participants. Respiratory.	Use of a respirator during work in a swine confinement facility.	Lung function tests Blood analyses Nasal lavage Self-reported symptoms	The respirator significantly attenuated the inflammatory response to exposure to swine dust.	15 Moderate
Stone et al., 2001 [30]	Non-experimental post study. No. 4 farmers. Chemical exposure.	Alternative forms of head protection from sun and chemical exposure during pesticide application	Self-reported: Wear hat Workers preferences. Laboratory: Fabric chemical analysis	The wide brim hat more effective than others at reducing sun and chemical exposure. Baseball hat preferred by for ease & looks.	13 Moderate
Engineering/Design					
Hallman 2005 [31]	Experimental controlled trial. Yes (no subsidy offered). 365 offers made to farmers. Safety equipment implementation.	ROPS subsidy offered ranging from 0-100% of cost of total ROPS retrofit cost.	Responses to offers sent	An incentive of 75-90% of the cost of ROPS retro-fitment returned the greatest number of participants per dollar offered. Barriers to participation: expense, lack of kit for specific tractor & hassle of undertaking retro-fitting.	17 Moderate
Myers et al., 2006 [32]	Retrospective cohort. Yes (no ROPS). 6,063 principal farm operators. Injury.	Use of a seatbelt during historical tractor overturns.	Self-reported: Tractor overturns	Use of a seatbelt & ROPS reduced injury cases by 29-5%. Seriousness of injuries reduced on ROPS tractors regardless of seatbelt use. No statistical testing of results	13 Moderate

Author	Design Design type Control type Subjects Outcome	Intervention Type	Measures	Findings	Quality of Evidence Quality score Quality rating
Ergonomic					
Earle-Richardson et al., 2006 [33]	Quasi-experimental pre/post trial. Yes (pre-trial muscle fatigue measures, subjects as own control). 95 apple orchard harvesters. Musculoskeletal fatigue, acceptability and productivity.	Hip belt with a hooking mechanism for attachment to the apple bucket to reduce the back, neck and shoulder musculoskeletal load. Placebo treatment hip belt without weight bearing hook.	One day muscle fatigue. Self-reported worker acceptability. Productivity – rate of bushels picked per hour.	90% of workers reported they would use hip belt and hook again. 100% of workers would use the placebo hip belt without hook again. Intervention reduced muscle fatigue from placebo by 5.35% (p=0.45). Productivity increased from original apple bucket from 8.13 to 8.80 bushels per hour (p<0.0001). Placebo also increased production .	19 Moderate
Gregory et al., 2006 [34]	Quasi-experimental pre/post study - laboratory experiment. Yes – (no intervention, subjects serve as own controls). 12 sheep shearers. Musculoskeletal strain.	A trunk harness used to reduce the overall musculoskeletal strains associated with LBP during a high load agricultural task.	Posture & cumulative load measurement.	Significant reductions in musculoskeletal loadings and postures associated with lower back pain found with use of shearing trunk harness.	17 Moderate
Milosavljevic et al., 2004 [35]	Quasi-experimental pre/post study – laboratory experiment. Yes (no intervention, subjects serve as own controls). 12 sheep shearers. Musculoskeletal forces.	A trunk harness used to reduce the overall musculoskeletal strains associated with LBP during a high load agricultural task.	Musculoskeletal compressive and shear force measurement.	Significant reductions in musculoskeletal loadings and postures associated with lower back pain found with use of shearing trunk harness.	17 Moderate

Author	Design Design type Control type Subjects Outcome	Intervention Type	Measures	Findings	Quality of Evidence Quality score Quality rating
Southard et al., 2007 [36]	Quasi-experimental pre/post study - Laboratory & field experiment. Yes (current standard scales using shoulder press operation, subjects serve as own controls). 7 subjects.	Two ergonomic interventions (the handle attachment & lever arm) were used to reduce the back and shoulder biomechanical loading during weighing calves.	Laboratory: Muscle activity/load. Field: Digital photos for biomechanical modelling. Self-reported symptoms.	Intervention had a significant effect reducing the muscle activity and regions of body stress with both interventions. Considerable reduction in the biomechanical loading in the field observed as well. Farmers reported less muscle strain in back and shoulders. The lever arm was the most effective intervention for weighing calves.	12 Moderate
Stal et al., 2003 [37]	Quasi-experimental pre/post study. Yes (no support arm, subjects serve as own controls). 11 milkers without MSD symptoms in wrists or hands.	A support arm to reduce the weight of the milking cluster to reduce the biomechanical stress during the attaching task for developing MSD of the forearm, wrist and hand.	Muscle activity/load. Flexion mobility.	Decrease in muscle load with intervention. No decrease in muscle recovery. The velocity was significantly lower with intervention. Milking with a support lowers the muscle load and velocity thus reducing the risk of developing MSDs in the wrist and hand.	15 Moderate

Author	Design Design type Control type Subjects Outcome	Intervention Type	Measures	Findings	Quality of Evidence Quality score Quality rating
Health screening					
Jenkins et al., 2007 [38]	Non-experimental pre-post cohort. No (subjects used as own controls). 601 farmers. PPE use & hazard reduction.	Hearing and respiratory screening followed by targeted education, PPE dispersal and medical referrals.	Self-reported: Personal protective equipment use. Hazard abatement.	A 25% improvement in use of PPE was observed. A 30% improvement in respiratory hazard abatement was observed. No statistical testing results.	14 Moderate
Rydholm & Kirkhorn 2005 [39]	Non-experimental pre-post cohort. No (subjects used as own controls). 378 farmers. Safety behaviour.	Health fair consisting of health screening followed by specific education, presentations and posted recommendations.	Self-reported: Compliance with recommendations Changes in lifestyle and work practices. Use of PPE.	39% reported making a lifestyle change after the health fair. 22% reported a health improvement. 47% reported work practice change after the health fair with 40% using appropriate respirators, 21% hearing protection, 38% sunscreen/hat. No statistical testing results.	7 Poor
Multi-part interventions					
Forst et al., 2004 [40]	Quasi -experimental pre-post cohort with non-randomised control. Yes (glasses without training). 786 migrant farm workers. Injury & safety knowledge.	Promoter assigned to block A to distribute safety glasses, promotional material and to train workers, block B to distribute safety glasses and promotional material only.	Observation of wearing glasses at work. Knowledge on eye injury and prevention. Risk perception. Number of eye injuries (surveillance)	Significant increases in self - reported use of safety glasses in all groups. Largest change observed in group given training. Significant improvements in observed use as well.	19 Moderate
Mandel et al., 2000 [41]	Quasi-experimental pre/post prospective cohort with control group. Yes (no intervention). 508 farmers aged 40+ (186 intervention, 322 control). PPE use & safety knowledge.	Delivery of a multipart safe pesticide use intervention: Physician seminar Community interventions: school curriculum, educational materials deliver to homes, displays.	Self-reported: PPE use Pesticide beliefs and practices.	Increase in wearing gloves and other protective clothing while using pesticides. Only association with increased use of other protective clothing significant.	16 Moderate

Author	Design Design type Control type Subjects Outcome	Intervention Type	Measures	Findings	Quality of Evidence Quality score Quality rating
Rasmussen et al., 2003 [42]	Experimental randomised controlled trial. Yes (no intervention). 201 farms, 990 farmers. Injury & safety behaviour.	Farm safety check and farm safety day.	Self-reported: Injury registration. Safety attitudes, behaviour and perceptions. Observed: Post farm safety audit - intervention group only.	Significantly improved safety scores with intervention. 30% reduction in injury rate within intervention group & 42% reduction in medical treated injuries with intervention. Reduction rates ns.	20 High
Rautiainen et al., 2004 [43]	Experimental randomised controlled trial. Yes – (no intervention). 316 farmers (152 interventions, 164 controls). Injury.	Multi-part intervention: Health screening Farm safety review Education Financial incentives	Self-reported: Health problems, injuries, occupational histories Observed: (intervention only) annual health screening, farm review.	No significant difference in injury rate or characteristics between groups.	22 High
Other interventions					
Faucett et al., 2007 [44]	Trial 1: Experimental randomised controlled trial. Trial 2: Quasi-experimental pre-post intervention trial with cross-over. Yes (on standard breaks). Trial 1: 66 Strawberry pickers, trial 2: 32 orchard workers. Musculoskeletal symptoms.	Modification of standard legislated rest breaks to include for an additional 5 min break per full hour worked in which there was no scheduled break – a full 20 minutes extra breaks.	Discomfort & pain site body diagram. Pain faces scale. Fatigue severity scale.	Trial one: Significant reduction in musculoskeletal symptoms. Trial two: Significant declines in musculoskeletal symptoms and fatigue when in experimental rest schedules.	20 High
Rautiainen et al., 2005 [45]	Quasi-experimental interrupted time series. No (control time periods). 132,134 injury claims (1990-2003). Injury.	Premium discount on insurance costs provides an incentive to reduce injuries in farmers.	Number of injury claims made. Number of days off work.	A 10% decrease in claims rate was observed after the discount implemented. The injury reduction was not observed across all injury severity levels. Significant reductions of 8-19% were observed for the first 4 least severe categories (≤ 29 day off work) but not the most severe (≥ 30 days off work).	Not assessed

Results of literature review

Educational Interventions

Fifteen studies were classified as educational interventions of which 8 were pertinent to children on farms and 7 pertinent to adults on farms.

Educational interventions varied in focus from school-based interventions, such as school lessons for children, to community-based interventions, such as community camps and safety audits. All the interventions identified targeted general farming hazards with none specifically targeted towards the hazards associated with a particular commodity type. One study evaluated an educational intervention in both migrant and non-migrant farming populations [17]. The educational interventions will be discussed separately for children and adults.

Children

The 8 papers evaluating education interventions to reduce childhood agricultural injuries can be further sub-classified into 5 main groups based on the means of dissemination of the educational information: schools based lessons (n=4), other community organisational programmes (n=1), farm safety camps (n=1), legislated training intervention (n=1) and child development specific guidelines (n=1). The programs included in this review are presented in Table II.

The schools based lessons, community organisational programme, farm safety camp and legislated training intervention targeted children primarily, while the child development specific guidelines targeted farming parents as the primary decision maker with regards to allocating childhood farming activities. Primarily the evaluations investigated changes in safety knowledge, attitudes and behaviours, with the majority of studies presenting self-reported changes. Few studies validate these self-reported outcomes with the exception of an observational study of farm safety behaviour after the intervention [15, 20]. One study [46] included self-reported injuries as the outcome of interest while a further study used traffic crashes involving tractors from official traffic crash reports [47].

School-based interventions

School based lessons were the most popular singular approach evaluated in the childhood educational intervention literature with 4 papers reporting two separate school based lessons/units used in the United States.

The Agricultural Disability Awareness and Risk Education Model (AgDARE) was represented by 3 papers evaluating the intervention's effectiveness at moving adolescent students from contemplation of the safety consequences of farm safety behaviour to acting on the behaviour in order to improve safety on the farm, as based on the Transtheoretical Stages of Change Model [15, 20, 21]. The AgDARE programme consists of interactive physical and narrative simulation exercises on farm safety. The quasi-experimental cross-over study design was conducted in 3 US states (Mississippi, Iowa & Kentucky) and all papers were assessed to be of moderate methodological quality. The two intervention groups differed in the order they received the narrative and physical components of the intervention. **Kidd et al., (2003)** and **Reed and Kidd (2004)** reported the results of the pre-post study with statistically significant improvements in farm safety attitude and behaviours, as well as

significant improvements in the contemplation and action subscales, indicating a positive shift in adolescents contemplating safety on the farm and improving farm safety behaviour by taking more safety action steps on the farm, following the intervention [15, 21]. There was no difference in scores with the ordering of the interventions. In addition two papers of moderate methodological quality **Reed et al., (2003)** and **Kidd et al., (2003)** present the results of one observational follow-up of these students in the farm environment finding changes in safety behaviour on the farm after the intervention, with these changes confirmed by parents or teachers [15, 20]. The observational study result further validates the self-reported improvements in farm safety behaviour with the AgDARE program, although a limitation of the observational study is the lack of control group for comparison to rule out other influences on farm safety behaviour. The authors conclude that the AgDARE school curriculum program is effective in positively changing adolescents' farm safety attitudes and behaviours. This was confirmed by the observations of students making changes in work behaviours on the farm and influencing farm safety practices on the farm. These combined results indicate the AgDARE safety curriculum influences safety behaviour beyond the classroom setting. A limitation to this suite of studies is the lack of evidence of the effect of the safety curriculum on reducing childhood agricultural injuries. Further limitations are the lack of baseline observations of farm safety behaviours for comparison and a lack of a control group for the observational component of the study.

The second curriculum based intervention was the Kids and Communities Count Farm Safety Lesson [17] the follow-up to the Kids Count Lesson [48] as previously reviewed by Hartling et al. (2004). **Liller and Pintado (2005)** presented the effectiveness evaluation of the 45 minute safety lesson using a non-experimental "staggered pre-post test" design assessed to be of moderate methodological quality [17]. This evaluation of the Kids and Communities Count Farm Safety Lesson improves upon the previous study by matching students pre and post test surveys. The lesson involved the same visual and interactive Kids Count Lesson based upon the North American Guidelines for the Assignment of Agricultural Tasks (NAGCAT) previously evaluated [48] and was delivered in both English and Spanish, the predominant language of migrant groups in the Florida region where this trial was undertaken. In addition parents were surveyed with regard to their child's safety behaviour on the farm. The trial in two elementary schools reported statistically significant increases in mean safety knowledge scores after the intervention and displayed the ability to reach both migrant and non-migrant children. The self-reported survey of parents indicated that the majority of children had made changes to their behaviour on the farm. While the authors conclude this study provided evidence of efficacy in improving farm safety knowledge in migrant children there are several important limitations to the study. The main limitations include the use of a non-randomised design, matching only occurred for one school, information on changes to behaviour was reliant on self-reports from parents and that the generalisability of this study's findings are limited to the migrant population.

Community-based interventions

Community based interventions identified included a farm safety camp, a youth organisation farm safety program, a set of child development based guidelines and a legislated tractor training program.

Lee et al., (2004) presented the findings of the evaluation of a farm organisation partnership education program with Future Farmers America [16]. This high quality cluster randomised controlled trial investigated the effect of the program on safety behaviours and attitudes, and injury experiences 3 months after the intervention. The intervention consisted of two groups: the first group was given the standard intervention consisting of the health and safety program

with educational resources, formal training and guidelines, while the second group was given the standard program with extra program resources, free supplies of PPE and personal contact with a local expert supported by a financial gratuity. Although increases in mean safety behaviour and attitude scores were observed post intervention the differences between the treatment groups and controls were not significant. While a quarter of students reported an injury in the last 3 months there was no significant difference in self-reported injuries between the groups. While the intervention was found to have had no substantive effect on safety knowledge, attitudes, activities or injury experiences the authors do note this study's findings may have been undermined by inconsistent implementation of the program across chapters which was beyond the control of the study coordinators. A further limitation in this study was the lack of evidence of program efficacy before testing the efficacy of various dissemination strategies.

McCallum et al., (2005) evaluated the efficacy of a community day camp intervention [19] using a pre-post prospective cohort study, assessed to be of moderate methodological quality. The farm safety day camps were organised to provide an interactive age appropriate educational program on farm safety to small groups of children aged 8-13 years. Data were collected for 3 years worth of day camps. Statistically significant increases in self-reported farm safety knowledge and behaviour from baseline levels were reported although these improvements were moderate in size. These improvements were observed 3-4 months after attendance at the farm safety day camp suggesting knowledge and behaviour changes are retained in the medium term after the day camp. The authors identify the limitations of their study as follows: possible differences in the delivery of the program to children (lack of compliance with intervention); seasonal effects of measurement as all camps run at differing times of year, the lack of a control/comparison group; the self-reported nature of the outcomes; and the lack of longer term follow up of day camps effect beyond 3 months.

A child development based intervention, the North American Guidelines for Children's Agricultural Tasks (NAGCAT) was aimed primarily at parents as the primary person responsible for allocating children to farm tasks [14]. **Gadomski et al., (2006)** reported the results of a randomised controlled trial, assessing the use of an enhanced dissemination strategy to influence the uptake and use of the guidelines by parents. The study was assessed to be of high methodological quality. The use of a face to face educational encounter during a farm visit to introduce the NAGCAT guidelines, followed by modest booster interventions, achieved a 52% reduction in NAGCAT preventable injuries, although this difference was not statistically significant. A significant increase in the time to NAGCAT preventable injury and increased safety changes implemented on the farm were also found for the intervention group. Additionally the enhanced dissemination of the guidelines were found to delay the initiation of some dangerous farm tasks by farming children with the difference between the groups close to achieving statistical significance. Interestingly a pre-intervention screening was undertaken in this trial. All participating parents were given a questionnaire to gauge parents existing knowledge on childhood agricultural injuries and their level of concern for their children with regard to agricultural injury. Those parents identified as having a low level of concern regarding childhood agricultural injuries received a brief pre-intervention consisting of review of child injury fact sheets undertaken by an educator prior to receiving the intervention. While 37% of intervention participants were given the pre-intervention review, no analysis is presented of the effect pre-intervention had in enhancing the effectiveness of the enhanced dissemination intervention.

Marlenga et al., (2006) evaluated a legislated training intervention using a quasi-experimental interrupted time series analysis [47]. This paper has not been evaluated for methodological quality due to the study design not fitting the evaluation framework of Downs

and Black [1]. This study design is generally considered to be a valid design for evaluating the effectiveness of interventions [49]. The legislative act prohibited any youth younger than 16 years of age from operating a tractor on a highway unless they had successfully completed a tractor certification course. The evaluation found that the traffic crash rate, involving youth deemed “at fault”, was not reduced after the initiation of the full law. There were no reductions in the type, or number, of crashes attributed to youth tractor drivers. The authors conclude that mandating an educational approach to dealing with tractor crashes on highways involving youth drivers is an ineffective strategy for promoting farm safety, especially when the program is not tailored to the major causes of tractor injuries in this population. Limitations to the study identified by the authors include: the small number of cases, coupled with substantial variability over time reducing the overall power to statistically detect an effect; the inability to determine the training certification status of any youth involved in crashes that could result in the examination of the effect of training certification on overall crash figures; and the reliance on population estimates of as indirect measures of exposure

Table II: Characteristics of studies evaluating the effectiveness of interventions to reduce child injuries on farms

Authors/Years/Country	Primary Objective	Methods/ Study Quality	Intervention	Results	Author's conclusions
Gadomski et al., (2006) New York State, USA [14]	Evaluate the effect of active dissemination of the North American Guidelines for Children's Agricultural Tasks in reducing childhood agricultural injuries.	RCT involving 931 central New York farmers with resident or employed children. QI 25	Intervention: Lay educators visited farms to review the guidelines with farm family. Fact sheets of childhood injuries also reviewed if farmers displayed low levels of concern of farm injuries at baseline. Booster interventions: postcard during high-risk summer season, calendar, magnetic photo frame. Controls: Baseline survey only.	Injury incidence density: All age groups mean cumulate densities for work-related injuries 0.44 controls vs. 0.34 per 100 FTEs intervention (p=0.31). Children <7 years 1.36 per FTEs controls vs. 1.27 per 100 FTEs interventions (p=0.77) and 7-16 years 0.63 controls vs. 0.50 per 100 FTEs interventions (p=0.96). Time to NAGCAT preventable injury increased for intervention farms (HR 0.52, 95% CI 0.29-0.92, p=0.03).	Study demonstrates efficacy of active dissemination of guidelines followed by modest intervention boosters. Incidence of injuries lower in intervention group compared with controls. Additionally guidelines influence intermediary variables such as delaying ATV use, providing more supervision and making safety related changes on farm.
Kidd et al., (2003) Kentucky, Iowa, Mississippi USA [15]	Evaluate the effects of an educational intervention to prevent agricultural injuries in adolescents using the contemplation and action elements of the transtheoretical model of change.	Quasi-experimental cross-over design, involving 21 schools and 790 participants in 3 states of the USA. Pre and post questionnaire with 1 year follow up visits for sub-set of treatment group. QI 17	Intervention 1: narrative simulations prior to physical simulations. Intervention 2: physical stimulations prior to narrative simulations. Control: no intervention.	Significant difference in terms of contemplation (mean score 3.3 treatment vs. 2.3 control, p<0.0001) & action (mean score 2.8 intervention and 2.0 control, p<0.0001) between the treatment and control groups. Some difference between group 1 and 2 with those receiving the narrative first scoring higher than those who received the physical simulation first but ns. Of visited students 25 (86%) of intervention group made safety behaviour changes post intervention.	Intervention considered to be successful in promoting change in adolescents. Modelling the program on the transtheoretical model of change can assist researchers in examining intervention effectiveness and long-term efficacy.

Authors/Year/Country	Primary Objective	Methods	Intervention	Results	Author's conclusions
Lee et al., (2004) 10 states, USA [16]	Evaluation of a rural youth health and safety initiative implemented in National FFA chapters across the US.	RCT involving the cluster randomisation of 123 National FFA chapters and 1167 students. Post intervention follow up 2 years. Pre and post surveys. QI 24	Standard intervention: partners program with educational resources, formal interactive training, and instructional guides. Enhanced intervention: standard intervention program with extra program guidelines and resource, free supplies of PPE and personal contact with local public health office, with \$300 financial gratuity. Controls: no intervention.	Mean scores post intervention: safety knowledge 2.7 standard, 2.8 enhanced and 2.7 control (p=0.43), safety consciousness 2.9,3.0 and 3.0 (p=0.47), leadership 3.3,3.3,and 3.3 (p=0.53), risk taking 3.2, 3.2, and 3.2 (p=0.38), self-esteem 3.8, 3.8 and 3.9 (p=0.69), safety campaign participation 2.1, 2.1 and 2.0 (p=0.67) and injury experiences 1.8, 1.7, and 1.7 (p=0.44).	No substantive effect of the intervention conditions on participants self-reported safety knowledge, attitudes, activities or injury experiences. The intervention was implemented inconsistently across sites effecting results.
Liller & Pintado (2005) Florida, USA Kids and Communities Count Safety Lesson [17]	“Examine the continued efficacy of a school-based farm safety lesson in migrant children and a similar lesson to the community”.	Pre and post-test trials involving 2 migrant elementary schools in Florida, USA. Pre and post surveys. Parental follow up survey 1 month post intervention. QI 17	Intervention: Kids Count Lesson delivered as part of MORE HEALTH program into schools. See above.	Mean safety knowledge score increased from 5.0 at pre test to 6.6 on the post test (paired t-test p<0.001) in the matched pre/post test participants (n=66). Over half of the parent's survey reported children practicing safety farm behaviours since the lesson. Qualitative evidence that lesson was effective in community group increasing safety knowledge.	Study shows the efficacy of the Kids Count lesson in improving safety knowledge among migrant school children, and reached parents and community members with farm safety messages
Marlenga et al., (2006) Wisconsin, USA [18]	Evaluate the effectiveness of a US state law (mandating compulsory tractor training), Wisconsin Act 455, in reducing highway tractor crashes involving youth operators.	Retrospective case series design using 146 motorised vehicle accident reports in youth aged 7-15 years in Wisconsin. QI not assessed.	Wisconsin Act 455 prohibiting any child younger than 16 years from operating a farm tractor on the highway unless the child has successfully completed a tractor certification course to the requirements under the federal regulations.	Rate ratios: Underlying time trend per quarter RR 1.01, 95% CI 0.98-1.05, (p=0.437), Full law effect (after 3 years) RR 0.58, 95% 0.21-1.57, (p=0.280). No reduction in proportion of crashes where youth were designated “at fault” nor in the type, or number of contributing circumstances.	Mandating an educational approach to dealing with tractor crashes on highways is an ineffective strategy for promoting farm safety when the programs not tailored to the major causes of tractor injury.

Authors/Years/Country	Primary Objective	Methods	Intervention	Results	Author's conclusions
McCallum et al., (2005) Kentucky, USA. Progressive Farmer Farm Safety Day Camp® program [19]	To assess changes in safety-related knowledge and behaviours among participants in the Progressive Farmer Farm Safety Day Camp® program.	Pre/post test trial involving 72 day camps and 1781 campers. Follow up 3 months post camp. QI 16	Farm safety day camps. No control or comparison groups.	Mean knowledge score improved from pre 5.52 (1.74) to post 6.62 (1.30), $p < 0.001$. Improvements in behaviour risk from pre 13.88 (5.89) to post 11.35 (4.60), $p < 0.001$. Risk exposure due to lack of ATV safety gear risk score decreasing from pre 8.89 (2.29) to 7.40 (2.07), $p < 0.001$ post. Larger increases in knowledge & behaviour risk scores observed for children with high levels of contact with farms.	Results support claims for the effectiveness of farm safety day camps for increasing knowledge and improving safety practices among camp participants. Improvements modest.
Reed & Kidd (2004) Agricultural Disability Awareness and Risk Education Model (AgDARE) [21]	Determine whether an educational intervention could move an adolescent from thinking about the safety consequences of farm work behaviour to acting on the behaviour in order to improve safety among teens.	Randomised controlled trial – randomised by school. (n=21 schools – 14 intervention/7 controls) Follow up farm safety audit of sub-sample 7-14 months post intervention QI 16	Intervention: School presentations of narrative and psychomotor simulation modules of program. Control: No intervention	Significantly greater improvements farm safety and perceived ability to prevent injury observed in intervention group compared with the controls. The intervention group scored higher on scales for both contemplation & action subscales. 76% of intervention group made at least one positive work safety behaviour change.	The curriculum program AgDARE was successful and effective in positively changing teens attitudes toward farm safety and their contemplation and action to reduce injury risk. Results indicated the intervention group thought more about safety and took more action steps to protect themselves.
Reed, Westneat & Kidd (2003) [20]	Assess the impact of AgDARE on work behaviour of students who participated in the safety education program.	Pre/post study – observational. Farm safety audit post intervention – observed work behaviour compared with self-reported baseline behaviours. QI 13	Received full AgDARE farm safety curriculum at school. No comparison group.	76% of student had made at least one change to their farm safety behaviours post intervention. Increasing use of PPE was also observed post intervention.	The ability of students to make changes in their own work behaviour and influence the overall safety of farm practices was evident. The quality of the observations added to the evaluation of the possible long-term influences of the AgDARE safety curriculum beyond the classroom.

Adults

The educational interventions aimed directly at adults on the farm can be sub-classified into 4 types based on the method of dissemination: educational courses/sessions (n=2); self-audit manual (n=1); media awareness (n=2), and discussion groups (n=2). The programs included in this review are presented in Table III. None of the studies identified investigated injury outcomes, as all focus on intermediary changes in safety knowledge, attitudes and behaviours, or reductions in farm hazards. One study presented the results of an intervention specially targeted towards migrant workers [28].

The educational courses/sessions targeted farm workers primarily, while the remaining intervention types primarily targeted farm operators as the key decision maker on the farm. The evaluations presented a range of outcomes including: changes in hazard exposure; PPE use; product awareness; safety knowledge, behaviours and/or activity. The majority of studies presented self-reported changes with two exceptions who obtained objective measures of farm hazard reductions post-intervention [24, 25]. One study conducted expert farm safety audits pre and post intervention to measure hazard reduction [25], while another conducted expert audits after the intervention [24].

Two studies of moderate methodological quality assessed the effectiveness of an educational media awareness campaign on the awareness and adoption of a number of safer farm production practices in the US state of Wisconsin [22, 23]. Both of these studies used a pre-post trial design with different samples in the same target population. **Chapman et al., (2004)** included a control group of strawberry growers [22], while **Chapman et al., (2003)** had no control group [23]. For both studies the intervention involved promoting a number of farming practices, or products, that were considered to reduce exposure to certain farming hazards associated with market gardening and dairy farming through radio, farming publications, and community promotions, such as university extension worker promotion and farm fairs. The production practices promoted were ergonomic mesh bags and standard produce containers for market garden use [22] and barn lighting, silo bags and calf feed mixing sites for dairy farming [23]. Both of the studies reported increased awareness of the products following the campaigns but this did not directly transfer into increased adoption of the production practices with the exception of a significant increase in the use of standard containers by market gardeners [22]. The authors in both studies concluded that farmer awareness of the promoted production practices was increased with the adoption of one practice, perceived as being a more profitable practice, significantly increased. Limitations of these studies identified by the authors include the use of a non-randomised study design, lack of a true control group not exposed to the intervention for one study [23], small sample sizes to discern differences, no attempt made to verify self-reports and no attempt made to measure injury outcomes.

The Agricultural Safety and Health Best Management Practices Manual (ASHBMP) uses pictures to show degrees of hazards and presents best management practices and hazard auditing to help farmers identify and correct hazards on the farm. **Legault and Murphy (2000)** assessed the audit manual in a high quality modified quasi-experimental pre-post study design [25]. The study design included a control group. All the participating farms were professionally audited at baseline and follow-up. The intervention groups received the audit manual plus feedback on the baseline expert audit, while the other intervention groups were given either expert hazard audit feedback or a manual only. No significant differences in hazard reduction, after the intervention, were observed between the groups. However, those who received the self-directed safety audit manual reported significant reductions in hazards on the farm post intervention compared with those not receiving the manual. The analyses

consistently showed those farmers with the ASHBMP manual had the greatest level of hazard reduction. A major limitation in this study was there was no true control group that did not receive the baseline audit to make comparisons with and baseline audits may have stimulated farmers to initiate their own health and safety action on their farms.

Two community educational sessions were evaluated with both studies focusing on educating farmers on pesticide exposures [26, 28]. The first, a high quality randomised controlled trial undertaken by **Perry and Laude (2003)** used presentations on pesticide-associated risks, a simulation of pesticide exposures, peer norms for pesticide handling from a local farmer and a hands on demonstration of proper use of protective equipment and safe handling practices with a chance for farmers to trial the equipment themselves [26]. The 3 hour educational session which was targeted at Wisconsin dairy farmers significantly increased safety knowledge, intentions and enhanced their cancer risk perceptions. In turn the intervention significantly reduced total pesticide use, as well as improving the use of personal protective equipment during pesticide application 6 months after the intervention. The authors identified the relatively short follow up as a limitation to this study not allow for maintenance of the pesticide program to be evaluated. A further limitation identified include the inability to validate self-reported finding with biomarker data which was collected but was not used due to small numbers. The authors conclude that it is possible to have at least a short-term effect on pesticide application practices and pesticide safety behaviour by increasing safety knowledge, intentions and cancer risk perceptions but the educational/behaviour skills approach tested in this study did not have a significant effect on pesticide exposure nor achieving full PPE use.

A moderate quality pre/post trial was undertaken by **Vela Acosta (2005)**. The one hour bilingual pesticide education session, used flipcharts and real, or simulated, scenarios to educate migrant workers in Colorado on sources of pesticides, absorption, toxicity, safety and first aid response [28]. The educational sessions resulted in significantly increased pesticide knowledge and safety scores. Adoption of safer pesticide work practices were significantly higher for those migrant workers in the readiness to change phase suggesting receptiveness to change and action can influence the uptake of safety behaviours. Follow-up was only 1 week after the intervention. Participants who perceived events in their lives were outside personal control (high external locus of control) were found to be less likely to adopt the intervention. Limitations to this study include a lack of validation of self-reported changes made, use of a non-randomised design, the short duration of follow-up and a small sample size reducing the power of the study.

Heikkonen and Laouhevaara (2003) evaluated a farm safety walk and discussion approach to improving agricultural health and safety in a moderate quality pre-post study undertaken in Finland [24]. The pre-post study included a non-randomised control group. The farm safety walk through involved hazard identification and discussion. The farm safety “walk through” intervention required the small groups of farmers to direct the walk through without expert direction thus empowering the group of farmers to take control of the session. The control group was directed by experts. Significantly more changes were made to the intervention farms in comparison to the expert lead sessions 18 months to 2 years after the initial intervention. The authors concluded that both forms of walk through and discussion were positive with the empowered farmer groups producing more changes in the work environment. The empowered groups were thought to allow for the creation of new social relations, and provide opportunities for farmers to learn from each other and share their experiences compared with the expert lead groups. These empowered groups are also thought to provide farmers with more motivation to improve farm safety conditions. Limitations to the studies include the use of a non-randomised study design, the lack of information to assess

the external validity of the study with no real indication of whether subjects were representative of the farming populations or the farming population they were recruited from, differing period of recruitment possibly introducing seasonal effects, and a lack of blinding to the intervention.

In a further moderate quality pre-post study with a non-randomised control group **Stave, Torner and Eklof (2007)** assessed the efficacy of structured farm discussion groups on hazard reduction and safety behaviour in Swedish farmers [27]. Structured farm discussions involved participants receiving a structured diary for documenting and analysing hazardous events on the farm with these diaries discussed at farm meetings run by a farm health and safety expert over a period of 18 months. A second intervention group received additional informational “lectures” from their expert in addition to the structured diaries and discussion. The combined intervention of both the structured farm discussion meetings with or without the educational lectures significantly improved self-reported work safety measures compared to the controls. The intervention groups also had significantly lower scores for work stress and risk acceptance compared with the controls. The greatest single improvement was found with the group receiving the incident diary and support meetings without educational lectures but the authors do note that this group did start from a lower baseline work safety level than the other groups. There was no attempt to control for baseline work safety score in this study’s analysis which is a limitation to this study’s findings. Although it appears the self-identification and recording of safety incidents which possibly involved injury were a key component of the intervention no injury data is presented in this paper. Further limitations are the lack of a true control group not exposed to the intervention and the use of a non-randomised study design. The authors conclude that creating networks to provide social support, facilitating discussion and reflection may have resulted in a desired changed in farm safety activity.

Table III: Characteristics of studies evaluating the effectiveness of interventions to reduce adult injuries on farms

Authors/Years/Country	Primary Objective	Methods/Study Quality	Intervention	Results	Author's conclusions
Chapman et al., 2004 Wisconsin, USA [22]	Assess the effectiveness of media & public event awareness campaign for adoption of 2 production practices (standard containers and mesh bags) to improve labour efficiency and reduce exposures to musculoskeletal injury hazards.	Non experimental pre-post study with different samples at base (n=103) and follow-up (n=71) with a non-randomised control. QI 19	Media awareness campaign consisting of the following elements: Print mass media Public events Resource people Farmer to farmer discussion groups.	Significantly increased reports of exposure to print media campaign and conference or workshop information. Significantly increased adoption of standard containers only (38% to 54%). No significant increase in adoption of mesh bags (8% to 17%). Increases in awareness observed but ns. No significant increase in intention to adopt practices.	Better information flow to growers may be able to increase the speed with which agricultural practices with better ergonomics are adopted, especially with the practices are more profitable.
Chapman et al., 2003 Wisconsin, USA [23]	Assess the effectiveness of a media awareness strategy to increase flow of information to farmers for the adoption of 3 diary production practices that are safer and improve profits.	Non-experimental design pre-post study - different samples at base (n=421) and follow-up (n=426). QI 19	Media awareness campaign consisting of the following elements: Print mass media Public events Resource people Farmer to farmer discussion groups.	Increased reports of exposure to information from public events, private consultants, other farmers, and print media. Significant declines in unawareness of barn lights & feed mixing sites. Increased adoption of barn lights but ns.	Improving information flow to operation managers about safer, more profitable production practices may be a relatively easy way to supplement conventional injury control efforts in high-hazard industries.
Heikkonen & Louhevaara (2003) Finland [24]	To evaluate if walk-through surveys by empowered farmer teams are more effective than a conventional walk through by occupational health practitioners.	Controlled trail involving 64 farms in 3 regions of Finland. Pre and post questionnaires, health examinations at follow up at 1.5-2 years. QI 18	Intervention: Farmers held the key role during the walk-through survey. Control: Occupational health practitioners held the key role during the walk through survey.	Number of changes in working conditions were greater in intervention group with 4.4 mean changes per farm in intervention group compared with 2.5 in controls (p=0.008). Extensive changes (expenses > EUR 6000) 1.7 mean changes per farm in the intervention group compared with 1.0 in controls (p=0.063).	The experiences of both types of walk-through were positive however the empowered farmer group produced more changes in the farm work environment.

Authors/Years/Country	Primary Objective	Methods/study quality	Intervention	Results	Author's conclusions
Legault & Murphy (2000) Pennsylvania, USA [25]	“Evaluation of the alternative Agricultural Safety and Health Best Management Practices (ASHBMP) Manual to reduce farm work hazards.”	RCT involving 150 Pennsylvanian farm operators. Pre and post surveys and hazard audits. QI 20	Intervention 1: ASHBMP manual plus results of hazard audit, Intervention 2: ASHBMP manual only, group 3 - hazard audit results only. Control: received only easily obtainable health and safety fact sheets.	No significant difference between treatment groups in terms of hazard reduction effectiveness. Greatest hazard reduction observed with ASHBMP manual only treatment group. Significant difference in hazard reduction was observed with those receiving the ASHBMP manual reducing hazards more than those not receiving the manual.	ASHBMP an effective tool for reducing workplace hazards Analyses consistently showed farmers who had the ASHBMP manual had the greatest levels of hazard reduction.
Perry & Layde, (2003) Wisconsin, USA [26]	Evaluated the effects of a small-group intensive workshop educational intervention designed to increase personal protective equipment (PPE) use and to reduce direct pesticide exposure.	Randomised controlled trial in 385 (94 intervention/291 control) dairy farmers in Wisconsin. Post intervention surveys. QI 26	Intervention: 3 hour enhanced educational session delivering 4 targeted messages: 1) Evidence of cancers in farmers, 2) simulated pesticide exposure slide show, 3) feedback on self-reported exposures and PPE use and 4) a cognitive behaviour strategy to reduce pesticide hazards. Control: standard re-certification meeting.	Mean scores 6 months post intervention: pesticide safety knowledge 13.0 control vs. 16.0 intervention (p<0.05), pesticide safety intentions 8.2 control vs. 11.5 intervention (p<0.05), risk perception 6.5 control vs. 9.3 intervention (p<0.05). Percent use of glove during most recent application 62.5 controls vs. 70% intervention (ns). Percent use of any other protective gear 40% controls vs. 64% intervention (p<0.05).	The one-time educational intervention successfully increased protective equipment use. Intervention had short term effect on pesticide application practices and pesticide safety behaviour by increase safety knowledge, intentions and cancer risk perceptions.

Authors/Years/Country	Primary Objective	Methods/study quality	Intervention	Results	Author's conclusions
Stave et al., (2007) Sweden [27]	Test an intervention methodology aiming at stimulating farmers' and farm workers' safety activity.	Quasi-experimental design – controlled trial. Pre/post intervention surveys. QI 17	Interventions: The open process (O group) approach introduction of the basic concept involving arenas for discussion stimulating farm safety activity and management. The structured (S group) approach introduction of the basic concept and incident diary. The structured and information (SI group) approach involved delivery of the basic concept, incident diary and educational information.	Significant improvements in safety activity were observed post intervention for the total sample. At baseline the SI group had significantly higher initial safety activity than other groups. Results showed no significant differences in changed scores for the three different intervention approaches. A significant difference in safety measure score change was found for the open (O group) and structured (S & SI groups). Those participant given a structured approach showed a greater increase in safety activity than participants in the non-structured intervention approach ($p < 0.09$).	Results suggested that the intervention methodology of creating social networks, facilitating discussion and reflecting on risk manageability may have resulted in a positive have in safety activity.
Vela Acosta et al., (2005) Rock Mountain Region, USA. [28]	Evaluation of the High Plains Intermountain Center for Agricultural Health and Safety bilingual pesticide risk reduction program.	Controlled trial – pre/post testing by survey. Follow up 1 week after intervention. QI 16	Intervention: A 60 minute pesticide training program given in Spanish. Program covered information on pesticides, absorption & toxicity, chemical safety, first aid and emergency responses using flipcharts and case scenarios.	Significant improvements in mean pesticide knowledge and safety risk perception were found for the experimental group.	Study demonstrated the pesticide program improved farm workers pesticide safety knowledge and enhanced their perception of pesticide-related risks. Study demonstrated that the attitudes, beliefs and knowledge of a farm worker influences their safety related behaviour

Engineering and Design Interventions

As many farms still use older model tractors the inclusion of a ROPS (Roll Over Protective Structure) is considered to be a key intervention to prevent tractor-related agricultural injuries, many of which are fatalities. Interventions identified in this review were: 1) encouraging uptake of ROPS retrofitting on older model tractors or, 2) evaluating the effectiveness of seatbelt use alongside ROPS use to prevent tractor-related injuries. A summary table of these studies is presented in Table IV.

Hallman et al., (2005) conducted a cohort study that investigated the effect of offering differing levels of financial incentive for ROPS retrofitting of tractors in the Northeast US [31]. The financial incentive was offered at varying levels of subsidy (% subsidy: 0, 12, 25, 37, 50, 63, 75, 90 & 100) on the total cost of a ROPS retrofit, and additional help was given in arranging the retrofit or obtaining the ROPS kit. The paper was assessed to be of moderate methodological quality. While it was anticipated that the group receiving the 100% subsidy would have the greatest level of uptake the study found those receiving the 75% and 90% subsidy returned the greatest number of participants per percent dollar offered. The authors identified the following barriers to participation in this intervention: expense (despite subsidy), lack of the availability of a ROPS kit for certain models of tractor, and the inconvenience associated with arranging the ROPS kit and fitting. The authors conclude that, despite the use of financial incentives, there are still significant obstacles that need to be addressed if retrofitting of tractors is to be embraced by the farming community.

Myers, Cole and Westneat (2006) conducted a historical cohort study of farmers to investigate the use of a seatbelt during tractor roll overs in Kentucky, USA [32]. The paper was assessed to be of moderate methodological quality. Use of a seatbelt in conjunction with a ROPS keeps a person within the confines of the protective structure in the event of an overturn. This study found that the use of a seatbelt in combination with ROPS reduced injury cases by 5- 29% in this group in comparison to those not using a seatbelt with a ROPS. No statistical testing was carried out. The authors conclude that this study confirms the safety value of seatbelts in combination with ROPS for preventing farm injuries. Limitations of this study include the potential impact of recall bias with the use of retrospective self-reported data, the lack of the ability to generalise the results back to the source population, the exclusion of fatal injury events and permanent disability injuries from the analysis, and the lack of statistical testing undertaken on the observed results.

Ergonomic Interventions

Five papers were identified evaluating the effectiveness of ergonomic interventions on reducing musculoskeletal biomechanical loadings [33, 34, 36, 37]. Reduction of these musculoskeletal loadings results in less likelihood of a person developing gradual process musculoskeletal injuries. All the interventions were ergonomically designed equipment to either: 1) supports a part of the body, such as the back, during a repetitive farm task that places high stress on the musculoskeletal system; or 2) provides a more ergonomically appropriate piece of equipment to replace the current equipment for a particular agricultural task. All studies that we identified, that evaluated the efficacies of these ergonomic interventions, were assessed to be of a moderate methodological quality. A summary table of these studies is presented in Table IV.

Earle-Richardson et al., (2006) conducted a pre-post cross-over trial of moderate methodological quality in apple orchard harvest workers to assess the effectiveness of a hip belt and supportive hook to reduce the load on the back, neck and shoulders associated with

musculoskeletal strain [33]. The apple harvesters were randomly assigned into the treatment or placebo group, followed for 1 week then the treatments were crossed-over and participants followed for a further week. The placebo was the same hip belt without the weight bearing hook attached while the treatment group received the weight bearing hook. Pre-trial muscle fatigue scores were obtained. The majority (90%) of participants favoured the hip-belt giving the intervention extremely high acceptability amongst users. Differences in “one day” muscle fatigue scores between the intervention and placebo groups were small and not statistically different. The authors note that the measurement of muscle fatigue may not have been sensitive enough to detect the expected difference in muscle fatigue. Picking speeds were significantly faster with the hip belt intervention indicating there may be productivity gains with the more ergonomically appropriate apple bucket. The authors concluded that the belt was acceptable to workers, did not hinder productivity but the anticipated ergonomic benefits were not demonstrated using the one-day strength test. Limitations of this study include: the lack of a true non-exposed control group since all wear the hip belts in both the intervention and the control groups, the short muscle fatigue measurement duration of one day, and only one measure of muscle fatigue was used thus limiting the ability to detect any difference in muscle fatigue and other muscles’ compensatory behaviour.

Milosavljevic et al., (2004) conducted a pre/post controlled field study using professional shearers in New Zealand [35]. Shearers are required to adopt sustained flexed postures for prolonged periods of time and sheep shearing has been associated with the development of lower back pain. A trunk harness was fitted to the shearers to reduce the overall cumulative musculoskeletal strains associated with lower back pain. Three shearing tasks were evaluated each involving a different body position to position the sheep for wool removal and the evaluation was conducted under strictly controlled study conditions in a wool shed. Results indicated the use of the trunk harness significantly reduced both the cumulative large compressive and shear forces in the spine during the shearing task. The authors conclude that the use of a trunk harness may reduce the cumulative forces experienced by the spine during sheep shearing moderating damage to the spine and reducing low back pain as a result of shearing. The authors also note that it is unknown how the harness may protect the back from a sudden or unexpected force during shearing. Limitations to this study include the use of a non-randomised design, and the lack of external validity.

Gregory et al., (2006) conducted a pre/post field study using professional shearers in New Zealand [34]. The same trunk harness as evaluated by Milosavljevic et al., (2004) was fitted to the shearers to reduce the magnitude of spinal forces experienced by sheep shearers during the shearing task. Results indicated the use of the trunk harness significantly reduced the musculoskeletal loading and postures associated with lower back pain in this group of workers. The authors conclude that the use of a trunk harness may potentially reduce the risk of injury during sheep shearing but the increased time spent in a lateral bent position may potentially induce other types of musculoskeletal injuries. Limitations to this study include the use of a non-randomised design, and the lack of external validity.

Southard et al., (2007) conducted a pre/post study using both laboratory and field experiments to assess the effectiveness of two ergonomic interventions to reduce back and shoulder mechanical loadings during calf weighing [36]. The ergonomic interventions, one using a lever arm design and the other a handle attachment design, were developed to improve the body posture of the lifter and reduce joint loads during the repetitive and high strain agricultural task of calf weighing. Both interventions were found to have had a significant effect reducing muscle activity and the regions of the body experiencing musculoskeletal stress. The reductions in biomechanical loading were observed in both the laboratory and field studies. The lever arm design, although more cumbersome to use in the field, provided

the greatest reduction in muscle activity and joint loading. The authors conclude that either ergonomically designed method for weighing calves should decrease the risk of injury to the lower back and shoulders. The limitations to the study and the paper include the use of a non-randomised study design, the lack of a true control group and little information available on which to assess the internal and external validity of the results.

Stal et al., (2003) used a pre/post study to evaluate the ability of an ergonomic support to reduce the biomechanical stress associated with a repetitive task undertaken during milking dairy cows [37]. The intervention was a support arm that reduced the weight of the milking cluster thus reducing the biomechanical stress during the attachment task. The intervention was especially targeted at reducing the development of musculoskeletal disorders of the forearm, wrist and hand. Significant decreases in muscle load and velocity were observed with the intervention while there was no decrease in muscle recovery with the intervention. The authors conclude that milking with a support lowers the muscle load and velocity thus reducing the risk of developing musculoskeletal disorders of the wrist and hand. Limitations of the study and the paper include the use of a non-randomised study design, the lack of information to assess the external validity of the results, and the possibility of recruitment bias during selection of the study sample.

Table IV: Characteristics of studies evaluating the effectiveness of engineering and ergonomic interventions

Authors/Years/Country	Primary Objective	Methods/study quality	Intervention	Results	Author's conclusions
Engineering					
Hallman (2005) New York State, USA [31]	Determine the level of financial incentive required to motivate the maximum number of farmers to install RPS on non-ROPS equipped tractors and thus affect the greatest level of change within the farming community.	Experimental controlled trial. QI 17	Differing level of financial reimbursement on the total cost of ROPS fitting on older model tractors. Subsidies were offered on the basis of percentage of cost and not by a specific dollar value.	An incentive of 75-90% of the cost of ROPS retrofit returned greatest number of participants per dollar offered. A total (100%) subsidy only 80% of the offers were taken up. Barriers to participation: expense, lack of kit for specific tractor & hassle of undertaking fitting.	Study results showed that cost was not the only factor affecting farmers' reluctance to retrofit. The most activity per dollar was at the 75-90% level of subsidy.
Myers et al., (2006) Kentucky USA [32]	Determine the propensity of seatbelt presence and use as an intervention to reduce injury severity on ROPS-equipped tractors as a hazard on non-ROPS tractors.	Retrospective cohort of 6,063 principal farm operators. QI 13	Retrospective data collection – Seatbelt use in combination with ROPS.	Use of a seatbelt & ROPS reduced injury cases by 29-5%. Seriousness of injuries reduced on ROPS tractors regardless of seatbelt use – ROPS 1 death, non-ROPS 24 deaths.	ROPS in combination with a fastened seatbelt during overturn increases the likelihood of survival and prevented serious injury. Use of a seatbelt on a non-ROPS tractor is a hazard in the event of an overturn.
Ergonomic					
Earle-Richardson et al., 2006. New York State, USA. [33]	To evaluate a hip belt's effectiveness in three areas: worker acceptance, worker productivity and one-day muscle fatigue to the back and shoulder.	Quasi-experimental pre/post trial in 95 apple orchard harvesters QI 19	Intervention: Hip belt with a hooking mechanism for attachment to the apple bucket to reduce the back, neck and shoulder musculoskeletal load. Placebo: hip belt without weight bearing hook.	90% of workers reported they would use hip belt and hook again. 100% of workers would use the placebo hip belt without hook again. Intervention reduced muscle fatigue by 5.35% (p=0.45). Productivity increased from original apple bucket Placebo also increased production .	The hip belt was acceptable to workers, not hindering productivity, but the anticipated ergonomic benefits were not demonstrated using one-day strength testing.

Authors/Years/Country	Primary Objective	Methods/study quality	Intervention	Results	Author's conclusions
Gregory et al., (2006) New Zealand. [34]	To examine the effects of a trunk harness to reduce the overall musculoskeletal strains associated with LBP during a shearing.	Quasi-experimental pre/post study undertaken in the field with 12 sheep shearers. QI 17	Intervention: Trunk harness designed to support a portion of the upper body weight of shearers while in a shearing posture.	Significant reductions in musculoskeletal loadings and postures associated with lower back pain found with use of shearing trunk harness.	Results support the use of a trunk harness when shearing sheep as it significantly decreased the musculoskeletal load and strains associated with lower back pain.
Milosavljevic et al., (2004) New Zealand [35]	To determine whether the use of a commercially available back support harness would reduce spinal forces produced during sheep shearing.	Quasi-experimental pre/post study undertaken in the field with 12 sheep shearers. QI 17	Intervention: Trunk harness designed to support a portion of the upper body weight of shearers while in a shearing posture.	Significant reductions in peak and mean compressive forces at the thoraco-lumbar junction (approx 13%) & lumbosacral joint centre (approx 20%) with harness use (p<0.01). Significant reductions in anterior shear force also observed at same sites (approx 40% & 30% respectively) with harness use (p<0.01).	The back harness may be used for a reduction of cumulative force exposure on the spine during shearing. A cumulative reduction in these ergonomic forces over time may moderate damage to the spine and reduce the incidence of low back pain in shearers.
Southard et al., (2007) New York State, USA. [36]	To assess the effectiveness of two ergonomic interventions (the handle attachment & lever arm) to reduce the back and shoulder biomechanical loading during the common animal husbandry task of weighing calves.	Quasi-experimental pre/post study using 7 subjects. Study had laboratory & field experiments. QI 12	Two ergonomic interventions the handle attachment where a bicep curling action was required to lift the calf & the lever arm type scales where a leverage action was used to lift the calf.	Both interventions significantly reduced the muscle activity (8-71% cervicobrachial & 2-43% lumbar region). Considerable reduction in the biomechanical loading/stress in field observed (33-100% shoulder, 42-57% spine). Farmers reported less muscle strain back & shoulders. The lever arm was the most effective	Using either the "handle attachment" or "lever arm" should decrease the risk to the low back and shoulders during calf weighing.

Authors/Years/Country	Primary Objective	Methods/study quality	Intervention	Results	Author's conclusions
Stal et al., (2003) Sweden [37]	To evaluate the effectiveness of a support arm to reduce the weight of the milking cluster reducing the biomechanical stresses associated with developing MSD of the forearm, wrist and hand.	Quasi-experimental pre/post study in 11 milkers without MSD symptoms in wrists or hands. QI 15	Intervention: support arm on the milking cluster taking the majority of the weight of the cluster when not attached to a cow.	Decrease in muscle load by 24% and 17% for the biceps and flexor muscles with intervention. No decrease in muscle recovery. The velocity was significantly lower with intervention.	Milking with a support lowers the muscle load and velocity thus reducing the risk of developing MSDs in the wrist and hand. Since large scale milk production increases the time spent in milking and a quarter of time undertaking the milking task involves attaching cups, even a moderate reduction of the workload may reduce the incidence of injuries.

Personal Protective Equipment (PPE) Interventions

Two studies were identified specifically evaluating the effectiveness of certain pieces of PPE to reduce exposures to known farm hazards. A summary table of these studies is presented in Table V.

A randomised controlled trial was undertaken by **Palmberg et al., (2004)** to assess the effectiveness of a respiratory protection device on the respiratory tract during exposure to swine dust in a swine house [29]. The study was assessed to be of moderate methodological quality. Exposure to the endotoxins² contained within swine dust in a confined space can cause an intensive inflammatory response in the upper and lower respiratory tracts. Use of the respirators, equipped with a fine particle filter to specifically filter out gases, decreased exposure to the swine dust associated endotoxins by more than 90% compared to the control group. Respirators also significantly attenuated the inflammation response and respiratory symptoms experienced by subjects. The use of the respirator with a gas only filter only attenuates these respiratory reactions. In order to eliminate the health effects of swine dust exposure during swine farming, if reduction of exposure levels, is not possible the use of a respiratory filter with both gas and particle filtering would be needed. Limitations of this study and report include: the small sample size, the possibility of selection bias, and lack of information to assess the external validity of the findings.

Stone et al., (2005) undertook a pre-post study to assess the effectiveness of headgear to protect farmers from sun exposure and subsequent development of skin cancer in Midwestern farmers during pesticide application using a pre-post trial [30]. The study was assessed to be of moderate methodological quality. The authors were interested in the level of chemical and sun protection provided by alternative types of headwear than the recommended chemical resistant hats or hoods which, the authors report, are widely ignored by farmers when applying herbicides to crops. This study was interested focused on what type of headgear farmers find acceptable for use during pesticide application and the level of pesticide and sun protection offered by each type of headgear. All participants wore each type of hat for part of a workday when applying herbicide to crops and the hat fabrics were analysed afterwards for levels of herbicide on the hat. Chemical analysis found 12% of the hats tested were contaminated with herbicide with the highest level of contamination occurring on the hat type with the most absorbent material. The baseball cap returned more cases of headwear contamination. Farm workers opinions of headgear favoured the baseball cap in all aspects measured with the exception of sun protection and repelling rain/spray which was rated as poor. The best hat for providing pesticide and sun protection was found to be the wide brimmed “Booney” hat. The authors concluded that despite identified shortfalls in the sun and herbicide protection offered by the baseball cap, this was still the most favoured headgear of farmers in this trial. Limitations of this study include the small number of participants, the use of a non-randomised design, the lack of a control group using the recommended headwear, the lack of measurement of potential health effects due to herbicide exposures, and a lack of information to assess the external validity of the findings.

² Toxic natural compounds found inside gram-negative bacteria, which are released when bacterial walls breakdown. Endotoxins can cause blood born endotoxaemia and toxic shock.

Health Screening

Two studies were identified that use a health screening intervention to improve hazard reduction measures such as PPE use and on-farm hazard reduction. Both studies were undertaken in the United States and involved recruitment of study participants at agricultural health fairs and similar agricultural events. A summary table of these studies is presented in Table V.

Jenkins et al., (2007) evaluated the impact of health screenings combined with personal education on farmers' hazard abatement using a pre-post study of moderate methodological quality [38]. The study recruited voluntary participants at health fairs and trade shows, undertook hearing and respiratory screenings at recruitment, and provided expert feedback to each individual on their results. The screening and counselling sessions took 30 minutes to complete. Self-reported exposure information and health screening results were reviewed by a safety educator and safety information, sample PPE and a demonstration of PPE use was given to participants. Individual counselling was also given on simple hazard identification with regard to hearing and respiratory hazards. After 3 weeks those participants who reported exposure to noise or respiratory hazards, PPE usage was improved by approximately 25% in both groups. Hazard abatement was improved at follow-up for both respiratory and noise hazard, with hazard abatement improvements greater for respiratory hazards than for noise hazards. Limitations to this study are the self-selection of participants into the study, loss to follow-up was significant and not accounted for, screening may deliver the wrong message to those assessed to be "healthy" possibly instilling a sense of personal invulnerability with regard to the hazards targeted, and the use of self-reported outcome and hazard exposure data. Little statistical testing was also undertaken in this study. The authors conclude that the health-screening based intervention conducted at agricultural events is an effective means of reaching an at-risk population and affecting short term PPE use and hazard abatement. To maximise the impact of health screening and hazard abatement the authors suggest an additional on-farm intervention to assist farmers in identifying hazards and means of reducing them.

Rydholm and Kirkhorn (2005) assessed the effectiveness of stand-alone health screening at farm health fairs on a farming population's lifestyle and agricultural work practices using a poor quality pre-post study [39]. The study recruited voluntary participants at health fairs and trade shows, undertook hearing and respiratory screenings at recruitment and provided individualised feedback on work practices and lifestyle recommendations. Testing included audiometry, spirometry, blood pressure, vision, lipid and glucose screenings. The individualised recommendations were mailed back to the participant. The majority of participants reported having made a work safety or lifestyle change in the 6 months after the health screening intervention. Close to half claimed having made changes to varying aspects of work safety and 39% claimed having made a lifestyle change. Improvement in health status attributable to the screening was reported by 22% of participants. Work changes included use of personal respirators (40%), use of hat and sunscreen (38%) and hearing protection (21%). More structural and expensive changes such as shielding of Power Take-off (PTO) shafts and ROPS installation were rarely undertaken. The authors conclude the winter health fair is effective in modifying work practice and lifestyle behaviours in farmers. The 6 monthly interviews were viewed as being an essential part of the intervention, although not originally intended as such, as it reinforced and encouraged farmers who had made changes. There are many limitations to this study with the main concerns being the use of self-reported work safety and lifestyle change data, the use of a non-randomised design, the lack of a control group, and the potential role of selection biases with the voluntary sample.

Table V: Characteristics of studies evaluating the effectiveness of PPE and health screening interventions.

Authors/Country	Primary Objective	Methods/study quality	Intervention	Results	Author's conclusions
Health screening					
Jenkins et al., (2007) Various states USA [38]	Evaluate the impact of hearing and respiratory screenings combined with personal education on farmers' self-reported use of PPE and implementation of noise and dust hazards.	Pre-post study of 601 farmers recruited at health fairs and trade shows. QI 14.	Intervention: hearing and respiratory screening followed by targeted education, PPE dispersal and medical referrals.	Improved PPE use at follow-up hearing 25.2% (95% CI 17.2-33.2) and respiratory 27.3% (95% CI 20.2-34.4) Improved hazard abatement at follow-up hearing 13.2% (95%CI 7.5-18.9) and respiratory 30.7 (23.8-37.6).	Conducting interventions at agricultural events is an effective means of reaching an at-risk population. An intervention based on screening followed by education can increase short-term hearing and respiratory PPE use and hazard abatement .
Rydholm & Kirkhorn (2005) Minnesota, USA [39]	Assess the effectiveness of a stand-alone farm health fair on a farm population's lifestyle and agricultural work practices.	Prospective cohort – took part in health fair with follow-up at 6 months. Provision of ear plugs and respiratory masks for some? QI 7	Intervention: health fair & individualised responses recommending changes to lifestyle and work practices. Follow-up telephone calls 6 months later.	78% of call back participants reported either a work safety of lifestyle change. With 47% of active farmers reported making health safety changes, increasing their use of appropriate PPE for work tasks, while 39% of all participants reported making lifestyle changes.	Winter Health Fairs for the farming community are effective in modifying work practices and lifestyle behaviours in farmers.
PPE interventions					
Palmberg et al., (2004) Sweden [29]	Assess the effectiveness of a gas filtering respirator during work in a swine confinement facility to reduce exposure to the harmful effects of swine dust.	Experimental randomised controlled trial involving 22 previously non-exposed participants. QI 15	Intervention: Gas filtering respiratory mask. Controls: no mask.	Symptoms such as shivering ($p<0.01$), headache ($p<0.01$) and malaise ($p<0.01$) increased in controls post exposure. Only shivering ($p<0.05$) increased in intervention group. Lung function tests increased in controls compared to intervention PEF values ($p<0.08$). Inflammatory response increased in controls compared with intervention – neutrophils ($p<0.001$), monocytes ($p<0.001$).	While the gas filter attenuated allergic response to fully protect swine workers respirators with gas and particle filtering capabilities would be needed.

Authors/Country	Primary Objective	Methods/study quality	Intervention	Results	Author's conclusions
Stone et al., (2001) Mid Western USA [30]	Assess the effectiveness of alternative forms of head to protect from sun and chemical exposure during pesticide application.	Non-experimental pre-post study involving 4 farmers. QI 13	Intervention: 3 types of common headwear - baseball cap, "boonie" brimmed hat and baseball hat with tyvek cover.	The wide brim hat was assessed by self-reported to be more effective than others at reducing sun and chemical exposure. Baseball hat preferred by farmers for ease of use & looks. 12% of headwear returned chemical contamination. Most frequently baseball cap contaminated.	Although the headwear used in this study was unsatisfactory in terms of providing protection from sun and chemicals during farm work farmers prefer the more socially acceptable baseball cap over more appropriate headwear.
Other interventions					
Faucett et al., (2007) California, USA [44]	Assess the impact of alternative rest break patterns on ergonomic risks of prolonged stooped or squat tasks.	Trial 1: Experimental randomised controlled trial. Trial 2: Quasi-experimental pre-post intervention trial with cross-over. QI 20	Modification of standard legislated rest breaks to include for an additional 5 min break per full hour worked in which there was no scheduled break – a full 20 minutes extra breaks.	Trial one: Significant reduction in musculoskeletal symptoms ($p=0.01$). Trial two: Significant declines in musculoskeletal symptoms ($p\leq 0.01$) and fatigue ($p\leq 0.02$) when in experimental rest schedules.	The introduction of frequent, brief rest breaks may improve musculoskeletal symptoms for workers engaged in strenuous stoop tasks.
Rautiainen et al., (2005) Finland [45]	Assess the effect of a insurance premium discount program on the reported injury compensation claim rate and severity of injury claims.	Quasi-experimental interrupted time series. QI not assessed.	Premium discount on insurance costs provides an incentive to reduce injuries in farmers.	A 10% decrease in claims rate was observed after the discount was implemented. The injury reduction was not observed across all injury severity levels. Significant reductions of 8-19% were observed for the first 4 least severe categories (≤ 29 day off work) but not the most severe (≥ 30 days off work).	Premium discount decreased injury claims and decreased minor and moderately severe injury claims. The relatively low decrease in no-lost-time claims and relatively high decreases in moderate lost-time claims suggest that the decreases may not be explained by under-reporting along but a combination of under-reporting and a true injury rate decrease.

Other Interventions

Other interventions cover rest breaks (n=1) and insurance premium discounts (n=1). A summary table of these studies is presented in Table V.

Faucett et al., (2007) evaluated the introduction of additional rest breaks as an intervention to reduce ergonomic strain in workers engaged in strenuous harvesting tasks in California, USA [44]. The intervention involved regular rest breaks of 5 minutes per full hour for workers undertaking stoop tasks during produce harvesting. The study used two different trial designs: the first was a randomised controlled trial in strawberry workers while the second was a pre-post trial with a cross-over design in orchard workers. Overall the paper was assessed to be of high methodological quality. Both trials reported significant reductions in musculoskeletal symptoms and a significant reduction in fatigue was found in the second trial. The authors conclude that the introduction of frequent, brief rest breaks may reduce the symptoms of musculoskeletal discomfort and fatigue for workers engaged in strenuous work tasks. The authors noted a limitation to this study was the migrant population's limited understanding of English and literacy problems affecting the assessments, and the possibility of the effect of local labor-management relationships and cultural differences between the workforce and management.

Rautiainen et al., (2005) evaluated the effect of an insurance premium discount on agricultural workers' compensation claims in Finland [45]. The study was an interrupted time series design and was not evaluated for methodological quality³. The premium discount program involved a 10% reduction in insurance fees if the insured person had no compensated injury claim during the previous 12 months. It was thought the insurance premium savings could motivate injury prevention in agriculture. The outcome data came from compensated injury insurance data and a 10% reduction in the insurance claim rate was observed after the premium discount was implemented. Interestingly injury reductions were observed for the less severe injuries with significant reductions of 8 – 19% observed for injuries up to but not greater than 30 days off work. A corresponding reduction in more severe injuries resulting in greater than 30 days off work was not found. Limitations to this study include the uncertainties regarding the relationship between actual injuries and injury claims (ie. a reporting bias), use of claims rates rather than injury rates, under-reporting of minor injuries, and the possibility of other changes occurring simultaneously to the policy changes affecting injury rates. The authors conclude that the relatively low decrease in no-lost-time claims and relatively high decreases in moderate lost-time claims suggest that the decreases may not be explained by under-reporting alone but a combination of under-reporting and a true injury rate decrease.

³ ITS study design not evaluated by the methodological assessment criteria of Downs and Black (1998).

Multi-faceted Interventions

Multi-faceted interventions used a number of separate interventional approaches to attempt to reduce agricultural injuries. Four studies were identified using multi-faceted interventions of which all included one or more educational components mostly in conjunction with another intervention. Combinations of interventions can be classified as:

- education and auditing (n=1);
- education and PPE provision (n=1);
- multiple educational interventions (n=1); and
- health screening, hazard auditing and financial incentives (n=1).

A summary table of these studies is presented in Table VI.

Rasmussen et al., (2003) undertook a high quality randomised controlled trial known as the “West-Jutland Study of the Prevention of Farm Accidents” in Denmark using multiple educational and hazard auditing interventions in the prevention of farm injuries [42]. The intervention comprised of a farm safety audit and report undertaken by an expert with the farmer in attendance, and a one day safety course conducted by experts. The safety course included educational sessions from experts and peers as well as interactive discussion sessions and safety demonstrations. The study showed significant improvements in farmers’ safety behaviour, as well as improvements in safety standards on the farm. Injuries were reduced by 30% for all injuries and 40% for medically treated injuries in the intervention group. This difference was not statistically significant. The authors note that threats to the validity of their findings come from possible information bias from farmers self-reporting injuries, an excess of injuries pre-intervention in the intervention group despite randomisation, follow-up periods differing across seasons, and the study being prone to placebo effects (Hawthorne effect) reducing the likelihood of achieving statistical significance. Despite these limitations the study has considerable strengths including using a randomised experimental study design, following participants a year post-intervention, and involving many common types of farming allowing the results to be broadly generalisable to the wider farming community outside of Denmark. The authors conclude that, although not statistically significant with the current sample size, the magnitude of the reduction in injuries and the direction of the effect supported the conclusion that the intervention effect was positive. Additional support for this conclusion was provided by significant improvement in safety behaviour measures, an important intermediary factor on the pathway from intervention to improved injury rates. On the basis of this and other evaluations undertaken by the West Jutland research group this intervention is now provided to all Danish farmers.

Forst et al., (2004) undertook an evaluation of the effectiveness of community health workers promoting the use of safety eyewear in migrant farm workers in the US [40]. The evaluation was a pre-post study design with a control group and was assessed to be of moderate methodological quality. The intervention involved community health workers providing protective eyewear and educational training on use of the eyewear, as well as imparting knowledge on eye injuries. A further interventional group received eyewear from community health workers with no training, while the controls received eyewear from the farmer. Self-reported use of the eyewear increased significantly for all groups with the intervention group that received training returning the greatest increase after the 4 month follow-up. These self-reported results were supported by field observations. The group receiving training also reported the highest improvement in knowledge regarding eye health and safety. The authors list the limitations of this study as being the use of a non-randomised design by using opportunistic group assignment, the transience of the research subjects resulting in variable follow up, the questionable validity of using a likhert scale in this migrant population, and inconsistent eye injury surveillance resulting in patchy injury data that was discarded. The

authors conclude that use of community health workers as distributors of and trainers in the use of protective eyewear are an effective tool in improving the use of PPE and safety knowledge in the short term with regards to eye injuries and health. The authors note there is value in both the interventional approaches undertaken in this study: promotion by community health workers and provision of PPE.

Mandel et al., (2000) evaluated a multi-part educational intervention to reduce pesticide exposures in Minnesota, USA [41]. The effectiveness of the intervention was evaluated in a pre-post test study, assessed to be of moderate methodological quality. The intervention involved: a seminar directed at physicians to provide information on exposure to pesticides; education material delivered to households; community based panel displays; and a school based component where an elementary school curriculum is used to educate children about pesticides and prevent exposure. While an increase in the wearing of protective gloves and other protective clothing was observed for the intervention group, only increased use of other protective clothing was statistically significant. Those intervention farmers using protective equipment the least, prior to the intervention, had the larger effect compared to the controls. An analysis of the effect of the separate interventional elements was not presented. The authors conclude that although the magnitude of the effect observed is modest it was in the desired positive direction with farmers reducing pesticide exposure through the use of PPE. Identified limitations to this study are the non-randomised study design, the reliance on self-reported outcomes, and restriction of the generalisability due to using middle aged farmers.

Rautiainen et al., (2004) undertook a high quality randomised controlled trial from the Iowa Certified Safe Farm program to evaluate the effectiveness of a program to reduce agricultural injuries and illness in Iowa farmers [43]. The intervention program consisted of: health screening; a farm safety audit and review; education; and a financial incentive of \$US200 per year. Farmers were followed up on their injury and physical health experiences for 3 years post-intervention by self-report. After 3 years there was no significant difference in the risk of injury between the intervention and control groups with a final adjusted Rate Ratio of 1.08 (95% CI 0.86-1.37). A review of the injury descriptions found that only 10% of the injuries reported in this study could have been directly linked to intervention elements of the Iowa Certified Safe Farm program. A key threat to the validity of the study identified by the authors was the fact that participants were essentially self-selected knowing they had to pass a safety audit if they were assigned to the intervention group thus biasing this study towards already “safe” farms and reducing the relative effect of the intervention. The low initial recruitment rate of 6% and a high initial farm safety review pass rate of 86% suggest that “safe” farms may have self-selected themselves into the study. Other limitations included: the financial incentive and interventions themselves possibly providing an incentive to report injury biasing injury reporting; the lack of blinding of financial incentives to other participants possibly resulting in less incentive to report injury; and the reliance on self-reported injury data.

Table VI: Characteristics of studies evaluating the effectiveness of multi faceted interventional programs.

Authors/Years/Country	Primary Objective	Methods/study quality	Intervention	Results	Author's conclusions
Forst, et al., (2004) Illinois & Michigan, USA [40]	Evaluate the Community Health Worker (CHW) "promoter de salud" model as a tool for reducing eye injuries in Latino farm workers.	Controlled trial (cluster trial) involving 786 Latino farm workers from Illinois & Michigan, USA. Pre and post intervention questionnaires & field observations. QI 19	Intervention 1: glasses and training by CHW. Intervention 2: glasses distributed by CHW, no training. Control: glasses only distributed.	Average change in self-reported safety glasses use: Intervention 1, -1.48 (p<0.001), Intervention 2, -0.71 (p<0.001), Control -0.96 (p<0.001). Intervention 1 vs 2, -0.77, (p<0.001), intervention 1 vs. control -0.52, (p=0.03), intervention groups 1&2 versus control -0.65 (p=0.0004). Observed use of safety eyewear increased from 1.1% pre to 36% post for intervention 1, 0% to 5.2% for intervention 2 and 0% to 14% for controls.	All groups reported significant increases in use of safety glasses. Distribution of safety eyewear reinforced by training by CHW is the most effective way to ensure their use to protect eyes.
Mandel et al., (2000) Minnesota, USA [41]	The interventional study was initiated to gain further insights into enhancing safe pesticide handling among Minnesota farmers through a educational approach.	Pre-post study in 1,049 farmers. In this study ere were 186 farmers in the intervention and 322 in the control groups who used pesticides. QI 16	Intervention: Component 1 – physician seminar to provide information on pesticide exposure. Component 2 – community interventions including an elementary school curriculum, educational material mailed to farm households, and community panel displays.	Use of gloves relative change ratio 1.2 (CI 0.9-1.7) for those <75% time pre-intervention use & 1.0 (CI%0.9-1.1) those >75% of time pre-intervention use. Other PPE 1.5 (CI1.0-2.2) <75% time pre-intervention use & 1.1 (0.8-1.6) >75% of pre-intervention use. The overall relative change ratio (intervention to control) was 1.4 (CI 0.9 – 1.8) & 2.9 (CI 1.8-3.3).	Intervention increased safe handling of pesticides following intervention with increased use of both gloves and other protective clothing. The effect was larger amongst those who used protective equipment the least. There appeared to be potential for improving the safety of pesticide handling with a relatively simple multi-component education strategy.

Authors/Years/Country	Primary Objective	Methods/study quality	Intervention	Results	Author's conclusions
Rasmussen et al., (2003) Ringkoebing, Denmark West Jutland Study on the Prevention of Farm Accidents [42]	Examine the effects of a 4-year randomised intervention program that combined a safety audit with safety behaviour training in the prevention of farm injuries.	Randomised controlled trial n=201 (99 intervention, 102 control) QI 20	Intervention: Farm safety check & personalised feedback and a 1-day safety course	The intervention effect was estimated to be a 30% reduction in injury rate of all injuries, and a 42% reduction in medically treated injuries. None of these reductions were statistically significant. Significant safety behaviour changes were observed within the intervention group including improved use of PPE and active safety behaviour. Significant differences in observed farm safety behaviours in intervention group.	Study showed improvements in farmers' safety behaviour after the intervention program. Injuries were substantially reduced in the intervention group, post intervention. Reduction was more marked for injuries requiring medical treatment.
Rautiainen et al., (2004) Iowa, USA Iowa Certified Safety Farm program [43]	Demonstrate if the CSF program reduces farm-related injuries, illnesses and associated costs.	Randomised controlled trial, n=316 farms(152 intervention/164 control) Matched controls and interventions farms – commodity type and previous injury experience. QI 22	Intervention: Health screening, farm safety audit, education and incentives. Control: Payment for participation.	No statistically significant decline in injury rate was observed for the intervention group. No statistically significant difference in injury costs between groups either. No breakdown of the influence of the singular components of multi-phased intervention.	Study showed the CSF did not reduce self-reported injury rates and costs.

Pooled results

The previous reviews of Hartling et al., (2004) and De Roo and Rautiainen (1999) found 11 previous publications fitting the criteria used in the current literature review. Hartling et al., (2004) was the only review to evaluate the methodological quality of the publications identified and it is only these publications (n=8) that have been pooled with those identified in this current review. The pooled evidence is presented in Table VII.

Table VII: Pooled evidence of the effectiveness of educational interventions.

Note: Pooled evidence from Hartling et al., (2004) and current review. Marlenga et al., (2002) not included in pooled table as paper evaluated effectiveness of dissemination strategy only.

Intervention	Strength of evidence			
	Strong (high QI >19)	Moderate (moderate QI 19-11)	Some (low QI <11)	No significant results
Farm safety behaviours, attitudes and knowledge				
A – media campaigns		Chapman et al., (2003)		Chapman et al., (2004)
A – review/support sessions		Stave et al., 2007		
A – farm safety review or audit		Landsittel et al., (2001)* Heikkonen & Laouhevaara (2003) Legault & Murphy (2000)		
A – educational sessions		Vela Acosta et al., (2005)		
C – theatre		Elkind (2002)		
C – safety camps		Hughes & Hartley (1999)* McCallum et al., (2005)		
C – tractor safety		Cabbarra (2000)*		
C – school lessons	Reed et al., (2001)*	Liller et al., (2002)* Page & Fragar (2001)* Kidd et al., (2003) Liller & Pintado (2005) Reed & Kidd (2004) Reed et al., (2003)		Lee et al., 2004
Multi-faceted		Forst et al., (2004) Mandel et al., (2000) Rasmussen et al., (2003)		
Injury				
Multi-faceted interventions				Rautiainen et al., (2004) Rasmussen et al., (2003)
Child - tractor				Marlenga et al., (2006)
Child - guidelines	Gadomski et al., (2006)			
Pesticide exposure				
A – Educational lesson	Perry and Laude (2003)			

Key: A- adult targeted intervention, C – child targeted intervention. * publication identified and evaluated by Hartling et al., (2004).

Discussion

Overall, we identified an additional 33 peer-reviewed publications; which compares with 8 peer-reviewed publications identified in each previous reviews [12, 13]. Previous reviews identified a paucity of controlled studies to evaluate the effectiveness of interventions to reduce agricultural injuries. This review identified more published studies of improved methodological quality in comparison but there remains an absence of good quality studies that evaluate the effect of the intervention on injury outcomes.

In contrast to previous reviews, our study identified educational interventions as well as evaluations of regulatory and engineering/design interventions aimed at reducing agricultural injuries or reducing exposure to pesticides. The focus of farm safety interventions identified in this review was on:

- educating farming communities on safety knowledge, aimed at changing attitude and behaviours and/or inform / promote hazard identification;
- providing safer engineering and design features on farm machinery;
- the ability of personal protective or ergonomically designed equipment to reduce exposures;
- using health screening, organisational practices or financial interventions to stimulate changes in farm safety practices and behaviours.

All these interventions ultimately aimed to eliminate, reduce or control hazardous farm-related exposures in the farming community.

Effectiveness of interventions reviewed

Childhood educational interventions: The focus of childhood farm safety education interventions has been on education to do one of the following: change child safety behaviours; educating to allow for children to identify farm hazards themselves; or changing farming practices with regard to childhood involvement in farm activities focusing on the parent's role in the delegation of farm work activities.

There is a consistent and growing body of moderate quality evidence to indicate that school-based educational lesson interventions do have some influence on children's farm safety attitudes, behaviour and knowledge at differing levels of the school system and that this effect can stretch beyond the classroom to the farm. However the downstream effects of changing farm safety attitudes, knowledge and behaviours on childhood agricultural injuries remains to be examined. Moderate evidence of the efficacy of a single NAGCAT educational encounter followed by modest intervention boosters at reducing NAGCAT preventable injuries was supplied by a randomised controlled trial.

Rautiainen et al., (2008) undertook a meta-analysis of interventions for reducing occupational injuries in agriculture [50]. Two of the studies included in our review were included in the pool analysis for childhood educational programs [14, 16]. Pooled RCT data for educational programs aimed at children (n=2) returned a rate ratio of 1.27 (95% CI 0.51-3.16).

The collective evidence from the previous review [13], meta analysis [50] and this current review suggests that interventions such as school based farm safety lessons, farm safety camps and child agricultural task guidelines have some promise for improving child farm safety knowledge but the evidence for the downstream flow on to reducing injury is not evident.

An important gap exists in the published research in agricultural injury prevention interventions targeted at the high risk toddler and pre-school group (children aged <6 years). This gap has been identified in an earlier review [13] and little work has been published since to develop targeted interventions for this high risk group. Other childhood agricultural injury interventions are known to exist, such as the provision of safe, fenced play areas for young children [51], that have not been evaluated for the effectiveness of the intervention to reduce childhood agricultural injuries.

Adult educational interventions: The focus of adult farm safety educational programs has been on the following: increasing awareness of safer farm practices using media campaigns; use of farmer review, support sessions or farm safety reviews/audits to reduce hazards on the farm; and the use of educational sessions to improve farm safety behaviours, attitudes and knowledge, or reduce pesticide exposures.

There is conflicting evidence that media campaigns encourage the adoption of safer farm practices. In two intervention studies using media campaigns to encourage the adoption of 5 production practises considered to be more ergonomic and safer than existing products only one practice, the use of standard produce containers, was adopted by farmers, possibly due to the perceived cost-benefits of these containers.

In comparison to educational interventions in children, there are very few educational classroom based lessons/sessions aimed at adults that have been evaluated and published. Adult educational classroom based lessons/sessions that have been evaluated have been solely with regards to educating farmers on pesticide exposures. There is limited evidence from one study to support educational sessions improving farm safety knowledge, attitudes and behaviours with regard to pesticide use [26]. Similarly there is limited evidence from one further study that educational lessons lead to reduced pesticide exposure on the farm [41]. Together these studies suggest educational sessions have potential to change farmer safety perceptions and actual behaviours on the farm with regards to pesticide use.

There is a growing body of evidence that interventions involving environmental review such as a farm safety audit/review can result in lower farm hazard scores but there is little evidence that these reductions in hazard scores lead to any reduction in on-farm injury. Social support networks may act to reinforce environmental review interventions. Socially supportive mechanisms, such as small discussion groups, have been evaluated by two studies [24, 27]. The findings of both these studies suggest social supportive networks may be effective long term, giving farmers a forum to discuss issues relevant to them and share their health and safety experiences with other farmers in a non-threatening environment. Better quality evaluation of similar interventions would be needed to fully elucidate the potential of small discussion/work groups to reduce agricultural injuries but current evidence suggests some potential in this approach. Not only does this type of intervention increase safety activities but it has also been demonstrated to reduce work stress in farmers which has potential benefits for improving farmer mental health [27].

Keifer (2000) reviewed the effectiveness of interventions to reduce pesticide over-exposure and poisonings in worker populations, including agricultural workers, finding 17 articles examining this issue [52]. No studies were identified examining prevention programs on pesticide poisonings, rather they examined the effectiveness of protective equipment or handling methods to reduce exposure to pesticides. The evidence found was mostly generated from small studies conducted under controlled conditions and have little relevance for real working exposures to pesticides. In a meta-analysis the data from one interrupted time series study found legislation to ban Endosulphan pesticides in Sri Lanka lead to a decrease in

poisonings with an effect size of -2.15 (95% CI -2.64 to -1.66) [50]. This led to the recommendation that banning pesticides is an effective means to reduce pesticide poisonings. The combined evidence suggests that although banning pesticides is an effective means to reduce pesticide poisoning it is not an entirely practical intervention in our modern agricultural production systems. Reductions of pesticide exposures with improved PPE use and modified pesticide behaviour may be obtained with educational sessions/lessons. Likewise reductions in pesticide use may also be obtained with educational sessions/lesson but further evidence is required to confirm these findings.

The previous review of De Roo and Rautiainen (2000) found less methodologically rigorous published evidence than our review on the effectiveness of educational interventions at reducing agricultural injury. The lack of methodological rigour led this review to conclude there was insufficient evidence that educational interventions lead to reductions in agricultural injury with sole educational interventions. Rautiainen et al., (2008) undertook a meta-analysis of interventions for reducing occupational injuries in agriculture [50]. Two of these three studies have been included in our review [42, 43]. Pooled RCT data for those educational programs (n=3) aimed at reducing agricultural injury in adults the rate ratio was 1.02 (95% CI 0.87-1.20).

The collective evidence indicates that, in adults, educational interventions alone are able to deliver stable improvement in safety behaviour, attitudes and knowledge in situations where supportive networks are also provided. Where supportive networks are not provided, short term improvements in safety behaviour, attitudes and knowledge have been found. However there is little evidence that educational interventions alone are able to deliver a stable, long term reduction in injury in adults.

Engineering interventions: This review identified two studies investigating aspects of implementing ROPS retrofitting or enhancements to the basic ROPS operation. Use of a seatbelt enhances the protective ability of a ROPS structure reducing fatalities to a greater extent than ROPS use alone in tractor overturns [32]. Financial interventions covering the proportion of the total cost of the ROPS structure can improve the uptake of ROPS fitting but this work has highlighted that cost is not the only barrier to be addressed in attempting to improve ROPS coverage [31].

Most work on the effectiveness of ROPS and compulsory legislation to fit a ROPS to all operational agricultural tractors has occurred prior to this review [2]. Reynolds and Groves (2000) identified 14 studies, mostly interrupted time series examinations, in their review of the effectiveness of ROPS in reducing farm tractor fatalities [2]. Levels of ROPS implementation on tractors are very high due to compulsory European legislated requirements for ROPS installation on all operational tractors. Correspondingly fatality rates have dropped to extremely low rates in many European nations. The authors conclude there is a clear demonstration that installation of ROPS can virtually eliminate roll-over fatalities, with the exception of cases where seatbelts are not used in conjunction with ROPS. It is noted that a significant proportion of the reduction in ROPS fatalities may be due to the European requirement for crush proof cabs, which do not require the operator to wear a seatbelt but we do not have evidence to support this. Compulsory legislation for installation of ROPS on all operational tractors is by far more effective than voluntary safety standards. The Reynolds and Groves review concludes that engineering controls alone are not sufficient to reduce tractor-related injuries and interventions need to be directed at educational and incentive programs to increase the acceptance and uptake of ROPS interventions in the absence of legislation for compulsory ROPS installation.

A meta-analysis of agricultural injury prevention interventions undertaken recently has found ROPS on new tractors to decrease fatal injuries in farmers [50]. Legislation to increase the use of ROPS on tractors, requiring ROPS on new tractors sold after a certain date, was associated with a decrease of fatal tractor-related injuries over the long term (effect size -0.93 95% CI -1.02 to -0.03) while total injuries increased (combined fatal and non-fatal tractor-related injuries). There was no examination of the effect of retrofitting of ROPS onto older model tractors on tractor-injury risk.

The collective evidence indicates that ROPS are an effective means of reducing tractor-related roll-over deaths with fully enclosed cabs potentially more effective than open ROPS at reducing fatal injuries. Open ROPS are the most effective at reducing tractor-related rollover deaths if used in conjunction with seatbelts to keep the tractor operator within the protective framework during rollover. Installation of ROPS protection has been a significant issue, especially for older model tractors in operation on farms. Voluntary retrofitting of older model tractors with ROPS may not be the most effective means to reduce tractor-related roll-over deaths. There is limited evidence that the use of financial incentives alone to improve voluntary ROPS retrofitting is effective at improving ROPS uptake but there are other significant barriers to be overcome to encourage voluntary retrofitting. There is however, good evidence to indicate strong legislation making ROPS installation compulsory on all operational tractors can reduce, if not virtually eliminate, tractor related fatal injuries.

Ergonomics/PPE interventions: This review identified a small number of low/moderate quality studies evaluating the effectiveness of ergonomically designed equipment or personal protective equipment to reduce hazard exposure on the farm. Those studies which tested interventions in real world working situations suggest that a few ergonomic interventions would be feasible for use in farming practice to reduce musculoskeletal strain namely ergonomic hip-belts for orchard work, milking cluster supports for dairy farms, back support harness for sheep shearing and ergonomic scales for weighing calves [33, 35-37]. There was limited evidence from one study that use of a personal gas filter can attenuate respiratory inflammatory responses in animal husbandry workers [29]. Given the number of tasks undertaken on the farm involving exposure to physical or ergonomic hazards more PPE and ergonomic intervention development is needed in this area.

Davis and Katowski (2007) reviewed the effectiveness of interventions to reduce musculoskeletal injuries and disorders. The review found only 3 intervention studies that evaluated the use of ergonomic pieces of work equipment to reduce musculoskeletal strain. One study included by Davis and Kowtowski has already been described by our review [22]. The remaining 2 studies (not published in a journal therefore not included in our review) evaluated the effect of utilising more ergonomically sound methods of carrying agricultural loads with both studies displaying reductions in musculoskeletal strain and better postures.

The collective evidence evaluating the effectiveness of ergonomic interventions to reduce agricultural injury and disease indicates that the use of more ergonomically appropriate work tools, as well as modifying patterns of work/rest, may be feasible for reducing musculoskeletal pain symptoms in agricultural workers undertaking repetitive tasks. On the other hand the evidence of the effectiveness of PPE interventions to reduce exposures to farm-related hazards is less consistent: nevertheless, it suggests that the use of PPE may attenuate respiratory symptoms in workers. Overall the literature is small and uses small trials / studies to evaluate the effectiveness of the intervention. The lack of studies identified in this area and possible effectiveness of these interventions to reduce agricultural disease and injury highlights the need for further research, development and evaluation of ergonomic and PPE

interventions in the agricultural industry. Despite this there may be promise in investigating the use of ergonomic interventions for highly repetitive agricultural tasks.

Health screening interventions: There is an absence of evidence from two studies of poor methodological quality that offering health screening and individualised educational materials, or advice at health fairs is an effective intervention for changing farm safety behaviours [38, 39]. Improved delivery of health screening in a setting outside of health fairs may potentially improve the uptake and effectiveness of health screening but this remains to be evaluated.

Other interventions. There is limited evidence from one study that modifying patterns of work and rest may be feasible for reducing musculoskeletal pain symptoms in repetitive farm tasks [44]. More evidence is needed to further clarify the effects of this organisational intervention but it does hold promise for uses in many potentially physically fatiguing situations in agricultural work.

There is limited evidence found in our review from one study that insurance premium discounting may be effective at reducing injury claims [45]. A meta-analysis of this studies interrupted time series data evaluated the effect of the financial incentive intervention which initially decreased the injury claims immediately following the intervention (RR -2.68 95% CI -3.80 to -1.56) but did not have a significant effect over time (RR -0.22 95% CI -0.47 to 0.03) [50]. Further work would be required to fully elucidate the potential effects of insurance premium discounting on actual rates of injury, as opposed to compensation claims for injury.

Multi-faceted interventions. Two intervention programs involving a number of different interventional elements returned modest improvements in farm safety behaviour with regard to use of PPE [40, 41]. An educational component combined with PPE provision or multiple educational components can improve the uses of safety equipment on the farm.

The evidence on the effectiveness of multifaceted interventions to reduce injuries in farmers is absent, with only two RCTs reporting no statistically significant differences in injury rates between intervention and control groups [42, 43]. One of the RCT trials indicated that positive improvements can be made with a multiple educational and hazard auditing intervention, significantly improving farm safety behaviour and, although the resulting improvement in injury rates for the intervention group compared to the control was not statistically significant, the intervention effect was considered to be positive [42]. The other RCT reported some limitations that could have seriously undermined the effectiveness of the multifaceted intervention to reduce the key injury causes in this population [43].

Previous reviews identified further mixed results from multi-faceted interventions with respect to youth and adult interventions [12, 13]. Self-audit components have been previously identified as having the potential to reduce agricultural injuries. Our current review identified two further RCTs evaluating interventions using self-audit as one component of the intervention. Unfortunately the individual effect of the self-audit component was unable to be teased out from the contribution of the rest of the intervention but the indication from these studies is that self-audit may contribute, along with other educational interventions, to improvements in farm safety behaviour and possibly to a reduction in injury. The effectiveness of self-audits as part of a multi-faceted intervention to reduce agricultural injuries is by no means clear but it does hold some promise in the context of a multi-faceted intervention. More high quality research is therefore needed to fully elucidate the effect of multi-faceted interventions on injury outcomes. Multi-faceted interventions, where combinations of educational and other interventional approaches such as PPE provision or

self audit, are a promising interventional approach to improve farm safety behaviours, attitudes and knowledge. The evidence for multi-faceted interventions being effective at reducing injury is less clear but this approach could be considered to be potentially promising.

Issues to arise from the literature

Lack of targeting of interventions. Most prevention programs included in our review did not focus upon leading agricultural injury or health problems. In general the interventions did not cover the major risks, or hazardous exposures of the farming community. Most educational interventions focused on general farm hazard reduction and behaviour change, with these programs not entirely effective at reducing persistent agricultural health and safety problems. Examples of poor targeting of interventions are provided by the Iowa Certified Safe Farm program where evaluation of the intervention found only 10% of the injuries occurring during the 3 year follow-up period were actually preventable by the program [43]. Likewise the NAGCAT evaluation reported only half of the injuries sustained by children on the farm during the follow up period were covered by the guidelines[14]. Legislation to reduce traffic crash events on highways caused by youth drivers on tractors was concluded to be ineffective as the legislated tractor safety program failed to address the key causes of tractor crashes on highways [47].

Important gaps were also identified in the coverage of the farming populations. No interventions were identified targeting the high risk 0-6 year old child population. The education programs reviewed focus on farm operators/workers and children of working age in the first instance. There are also gaps in coverage of other farm family members like wives, and grandparents.

It is widely recognised that the farm workplace contains a wide variety of hazardous machinery, structures, natural features and tasks which are difficult to target with one intervention. The vastly hazardous nature of the farm environment underlines the need for a descriptive evidence base of agricultural injuries to allow for appropriately targeted interventions for the agricultural community. Matching interventional program content to key agricultural injury or health concerns and the hazards associated with these would increase the likelihood of successfully preventing agricultural injuries and poor health outcomes.

Reaching beyond education. Education processes are just one necessary part of a public health approach to occupational health and safety in farming. Our review identified more educational program evaluations than any other interventional approach. This may be due to a publication bias with educational interventions more likely to be published but it is evident that more emphasis on engineering, design and public policies are also needed in the agricultural sector. Other engineering/design, organisational and legislative solutions were identified but still there were few and the majority were evaluated using methods of suboptimal quality. Again interventions have to be well targeted to address the main health and safety concerns of the farming community with poorly targeted interventions at a greater likelihood of failure. For example, the Wisconsin legislated requirement for an educational approach to reduce tractor-related injuries in youth was poorly targeted, not addressing the major causes of these highway tractor crashes, resulting in no real reduction in injuries to youth [47].

Barriers to implementation of interventions. This review has highlighted the need to understand barriers to implementing interventions on farms more fully when designing interventions with a higher likelihood of success. For example, cost would be considered to be the main barrier to ROPS retrofitting but the results of Hallman et al., (2005) would

indicate that despite the offer of full total cost reimbursement there are still many other significant barriers to the uptake of ROPS.

Established theories of behavioural change. This review found very few interventions that were based on established theories of change. One example of an intervention identified that was based on a behaviour theory of change is the AgDARE program which uses the Transtheoretical Stages of Change Model to move adolescents from the phase of contemplation of the safety consequences of farm safety behaviour to the action phase where adolescents act upon the behaviour to improve safety on the farm [15, 20, 21].

Methodological considerations

Little examination of injury outcomes. Previous systematic reviews reported that program evaluations assessed mostly changes in safety attitudes, knowledge and behaviours, with only a few studies assessing changes in the incidence of injuries [12, 13]. The situation has not changed significantly with this updated review also identifying the majority of studies evaluated changes in safety attitudes, knowledge and/or behaviours. Although these are potentially important intermediary pre-cursors to lead to reductions in injury, there is little evidence for any flow on effect of changes in safety attitudes, knowledge and/or behaviours on injury outcomes. They can be regarded as a necessary but not necessarily sufficient condition for injury prevention. Few studies were identified that evaluated changes in the incidence of injury and, where this was evaluated, self-reported injury was used predominantly.

Study designs. Previous reviews have found little experimental evidence with the major study design being pre-post test methods, where control groups are not used, and there is poor use of randomisation and objective measures of outcomes [12, 13]. This results in a methodologically weak evidence base limiting the ability of these reviews to infer the effectiveness of the intervention on reducing agricultural injury or health concerns. An encouraging outcome of our review is that authors have used more rigorous study designs when injury outcomes are evaluated which can give us more confidence in these studies injury findings. While in the period of the current review the predominant study design is still the pre-post test there was increasing use of control groups (randomised and non-randomised) and increasing use of more rigorous randomised and controlled trials.

Limitations of the review

Unpublished studies. Previous reviews of the agricultural injury intervention literature have included conference proceedings and unpublished reports as previous rates of publication have been low [12, 13]. These forms of unpublished literature were not included in this review as more evaluations are making it to peer reviewed publication. Despite this, the review authors are aware of intervention evaluations in the agricultural sector that have not yet been published in the peer-reviewed literature. For example the evaluation of the effectiveness of an All Terrain Vehicle training program in Australia [53].

Possible exclusions. The review was restricted to studies published in English. Our scope was as inclusive as practicable but it is possible that the search criteria and combination of databases used may not have identified all possible studies for inclusion. The search criteria were heavily weighted towards educational interventions and may have resulted in under-identification of engineering and regulatory interventions. Hand searching of relevant journals did allow for the identification of engineering and ergonomic intervention papers not catalogued in the common occupational health and safety databases used.

Overall judgement of the evidence

Quantity, quality and consistency of findings. Despite improvements in the number of studies evaluating of educational interventions that have been published, there are still only a small number of evaluations studies on the effectiveness of alternative interventions such as ergonomic and legislative interventions. Sample sizes tend to be small and many evaluation studies are under-powered to detect statistically significant differences in effect. The quality of the published studies identified (as assessed using Downs and Black's criteria) is improving with more high quality studies found by our review compared with previous reviews (6 publications $QI > 19$ compared with 1 publication identified by Hartling et al., 2004) but the majority of evidence still comes from pre/post studies of moderate methodological quality. This lack of high quality published studies / trials may reflect the inherent difficulties of undertaking rigorous intervention evaluations in the farming community. The strongest evidence is provided by consistent RCT results, but the few RCTs identified, all examined differing outcomes. The consistency of study findings across differing types of study design was rarely evident. This lack of high quality, consistent evidence effects the progression of injury prevention programs within this community.

Generalisability. Overall, there is good generalisability displayed by the studies reviewed with a few exceptions due to using laboratory studies and restricted study populations. All studies reviewed were evaluated in the work setting (ie. on operating farms) or in schools. Very few studies were focused on a particular commodity group with all interventions generalisable to the whole range of farming commodity types. Direct generalisation to the NZ farming context is discussed below.

Research applicability. Most work identified was conducted and evaluated in North America, mainly the United States, with a few studies identified from Scandinavian countries, and only studies from low and middle income countries. Although these modern market OECD economies employ similar forms of agricultural practice to NZ, the economic, social, historical and political contexts do differ potentially limiting the direct applicability of the identified intervention evaluations to NZ. A distinct lack of studies from the Australasian region was also found resulting in little evidence in this review with a direct relationship with the NZ context. It is possible that these interventions may behave differently in the NZ context and may be more, or less, acceptable to the farming community than observed in the original country due to the differing context of agricultural practice in NZ. For example, attitudes to agricultural health and safety would be expected to differ significantly between farmers from Scandinavian farms compared with New Zealand farmers which may mean the "empowerment" approach to agricultural health and safety evaluated on Swedish farms may not be as effective in the New Zealand context. Nevertheless, in the absence of directly relevant evaluations of interventions to improve agricultural health and safety outcomes, these studies do provide evidence of areas for intervention and types of interventions that may be effective in other countries.

Overall findings. Two previous reviews on the effectiveness of interventions to reduce injuries in agriculture both concluded that there was insufficient evidence to recommend one particular interventional approach to reducing agricultural injuries in the farm community [12, 13]. Our updated review confirms these previous conclusions and provides further evidence that there is no single intervention type that is able to address the high rate of injury in the agricultural sector.

Conclusion

This review identified no one single strategy for intervention that was considered effective for all types of farm injury or disease reduction. The findings provided very limited evidence of interventions that were effective at reducing agricultural injuries.

The focus on occupational safety, rather than occupational health, in the interventions reviewed is obvious. Of the total studies only 10 evaluated the effect of interventions on agricultural health concerns. This is despite a known higher risk of poor health outcomes, such as suicide [8] and musculoskeletal pain [54], among farmers.

Controlling occupational health concerns is a process which is systematic, based upon the key principles of hazard identification, assessment and control. Hazard identification is an important step because it addresses the occupational health hazard directly. The focus of occupational health interventions needs to be on the key occupational hazards and diseases of concern to farmers: chemical (pesticide), physical (noise, whole body vibration), biological (zoonoses, respiratory disorders), ergonomic (manual handling) and psychosocial (isolation, long working hours & stress). This review identified no study that has looked at the key aspects of either hazard assessment, or particularly at hazard control.

The key findings are summarised as:

- Moderate evidence was found for interventions that were effective at improving farm safety knowledge, attitudes and / or behaviours but there was no evidence to support any subsequent reductions in injury.
- A few, mostly studies of poor scientific rigour were found evaluating intervention strategies for the reduction of exposures known to lead to agriculturally related health concerns.
- There is mounting evidence, although mostly of moderate methodological quality, to suggest that educational interventions such as farm safety camps and school lessons targeted at school aged children displayed efficacy in terms of improving safety knowledge, attitudes and/or behaviours in the short term.
- There is also mounting evidence, although again mostly of moderate methodological quality, to suggest that and farm environment reviews/audits targeted at adults displayed efficacy in terms of improving safety knowledge, attitudes and/or behaviours in the short term.
- The NAGCAT guidelines were found to be effective at reducing child farm-related injuries covered under the guidelines with moderate quality evidence provided by a single RCT trial.
- Supportive network mechanisms may lead to improvements in safety knowledge, attitude and behaviours longer term but these interventions have not been subjected to rigorous evaluation.
- There is no evidence to indicate these improvements in farm safety knowledge, attitudes or behaviours results in subsequent declines in rates of injury in the target groups.

- There was limited evidence from single studies that educational sessions lead to changes in farmer pesticide safety perceptions and reduced pesticide exposure on the farm.
- There was moderate evidence that multi-faceted educational interventions, with or without the provision of PPE, can improve the use of PPE.
- Evidence from this and previous reviews indicate that multi-faceted interventions are a promising approach to improve farm safety behaviours, attitudes and/or knowledge but the efficacy of multi-faceted interventions at reducing injuries is not entirely clear. Potentially a multi-faceted intervention using self-audit as one component may be effective at improving farm safety behaviours and practices and subsequently reducing farm injury.
- There was limited evidence from single studies that seatbelt use with ROPS is more effective at reducing fatalities than a ROPS alone, and financial rebate incentives alone are effective at improving ROPS retrofitting. Previous work has already established the effectiveness of ROPS and compulsory legislation to fit a ROPS to reduce tractor-related roll-over deaths.
- There was weak evidence from single studies that organised rest breaks and various ergonomic interventions are effective at reducing musculoskeletal symptoms, and personal gas filters are effective at reducing respiratory symptoms from swine dust exposure.
- There was weak evidence from a single study that insurance premium discounting may be effective at reducing injury claims with little evidence of any effect on actual rates of injury, as opposed to compensation claims for injury.
- Poor evidence was found for health screening and targeted education at health fairs being an effective intervention to stimulate changes in health and safety behaviours on the farm.

Recommendations

This review identified no one single strategy for intervention that was considered effective for all types of farm injury or disease reduction. The findings provided very limited evidence of interventions that were effective at reducing agricultural injuries. Moderate evidence was found for interventions that were effective at improving farm safety knowledge, attitudes and / or behaviours but there was no evidence to support any subsequent reductions in injury. A few, mostly studies of poor scientific rigour were found evaluating intervention strategies for the reduction of exposures known to lead to agriculturally related health concerns.

The studies identified by this review do not provide strong evidence for the establishment of evidence-based interventions applicable to the agricultural industry in New Zealand but do however point to the direction that could be taken. The following recommendations are made on the basis of this review of the effectiveness of agricultural interventions to reduce poor health and safety outcomes on farms:

General intervention considerations

1. *Address the key injury and poor health causes.* Interventions need to be designed to address the key exposure/hazards faced by the farming community. Targeted interventions have a greater likelihood of success. To implement this recommendation a solid scientific evidence base is essential to identify and to apply interventional strategy.
2. *Interventions to reach beyond educational interventions.* Interventional approaches other than educational approaches need to be considered to address the multitude of mechanical, physical, biological, chemical, musculoskeletal and psychosocial hazards faced by farmers within the farming environment. We would recommend the consideration of alternative interventions (ie. engineering, design, regulatory, ergonomic, financial and organisational) to be used alongside educational interventions.
3. *Multi-faceted interventions.* The inability to address agricultural health and safety concerns with a single educational, engineering or regulatory interventional approach leads us to recommend the use of a multi-faceted interventional approach to address these concerns. Interventions should be truly multi-faceted, including combinations of relevant educational, engineering/design and regulatory interventional components, where applicable, to address the key agricultural health and safety concerns.
4. *Consideration of the barriers to implementation of interventions.* Intervention design needs to consider how to include those farmers resistant to safety improvement in farming. Programs were found to respond better to groups with poor health and safety conditions at baseline. Steps such as identifying high risk, more resistant farmers at initiation of the intervention and providing targeted interventions to these groups may improve the outcome of the intervention.
5. *Sustained support.* Interventional programs work better if sustained over time in a supportive environment (ie. support networks, follow-up contact, booster interventions, farmer empowerment). The potential for other promotional activities to build upon programs with sustained support should be considered (ie. take place during times of heightened farm health and safety activity, have the support of key

stakeholder groups). Interventions are more successful if programs can be delivered in a receptive environment.

6. *Novel farm health and safety interventional approaches and leadership.* All approaches reviewed have targeted the farmer or farm manager attempting to influence through the farmer as the key decision maker in the farming operation. There is a whole chain of people involved in agriculture who may potentially be used to influence agricultural health and safety (i.e. financial and insurance groups, commodity groups, commodity purchasers). Alternative targets for intervention should also to be considered.
7. *Underpinning intervention with established models for behavioural change.* Few interventions use an established model for change to underpin the mechanism of how the intervention will introduce change in farmer behaviour, activities or knowledge and subsequently impact upon rates of injury. Using established models for change will increase the likelihood of success of the intervention.
8. *Pilot testing interventions in the New Zealand agricultural context.* Any future interventions targeted at the agricultural industry in New Zealand need to be piloted and evaluated for their effectiveness at reducing agricultural injury and disease in the New Zealand agricultural context (in NZ farmers and on NZ farms), before being implemented nationally.

Research Agenda Recommendations.

A future path for the development of agricultural injury and disease interventions in New Zealand is outlined taking into consideration the upcoming outcomes of the research programme “Effective occupational health interventions in agriculture: key characteristics of their development and implementation in New Zealand”. It is proposed / recommended that:

- a) The findings related to promising agricultural health and safety interventions for use in New Zealand will be presented to key stakeholder for consideration on the completion of the “Effective occupational health interventions in agriculture: key characteristics of their development and implementation in New Zealand” project.
- b) A program of development of appropriate interventions to reduce the burden of agricultural injury and disease will be formulated, drawing upon established models for change, in conjunction with key stakeholders.
- c) Any proposed intervention should be evaluated in New Zealand for its efficacy in controlled trials.
- d) If found to be efficacious under controlled conditions, the proposed intervention should be tested and evaluated its effectiveness under “field” conditions.
- e) If the intervention effect is positive, only then would the intervention be implemented on a national basis.

References

1. Downs, S.H. and N. Black, *The feasibility of creating a checklist for the assessment of methodological quality of both randomised and non-randomised studies of health care interventions*. *Journal of Epidemiology and Community Health*, 1998. **52**: p. 377-384.
2. Reynolds, S.J. and W. Groves, *Effectiveness of roll over protective structures in reducing farm tractor fatalities*. *American Journal of Preventive Medicine*, 2000. **18**(4S): p. 63-69.
3. Horsburgh, S., A.-M. Feyer, and J.D. Langley, *Fatal work related injuries in agricultural production and services to agriculture sectors of New Zealand, 1985-94*. *Occupational and Environmental Medicine*, 2001. **58**(8): p. 489-495.
4. Feyer, A.-M., et al., *Comparisons of work related fatal injuries in the United States, Australia and New Zealand: overall methods and findings*. *Injury Prevention*, 2001. **7**(1): p. 22-28.
5. Firth, H. and et al., *Low back pain among farmers in Southland NZ*. *Journal of Occupational Health and Safety - Australia and New Zealand*, 2002. **18**(2): p. 167-171.
6. McBride, D., H. Firth, and P. Herbison, *Noise exposure and hearing loss in agriculture: a survey of farmers and farm workers in the Southland region of New Zealand*. *Journal of Occupational Health and Safety - Australia and New Zealand*, 2003. **45**(12): p. 1281-1282.
7. Rothstein, D. and et al., *Chemical use among farmers*. *Journal of Occupational Health and Safety*, 2004. **20**(5): p. 459-464.
8. Gallagher, L.M., et al., *Suicide and occupation in New Zealand, 2001-2005*. *International Journal of Occupational and Environmental Health*, 2008. **41**(1): p. 45-50.
9. Marshall, S.W. and et al., *Overview of injury on New Zealand farms*. *Journal of Agricultural Safety and Health*, 1996. **2**(4): p. 175-190.
10. Lilley, R., et al., *The New Zealand child work-related fatal injury study: 1985-98*. *New Zealand Medical Journal*, 2004. **117**(1194): p. U891.
11. Landsittel, D.P., et al., *Evaluation of the effectiveness of educational interventions in the Pennsylvania central region farm safety pilot project*. *American Journal of Industrial Medicine*, 2001. **40**: p. 145-152.
12. DeRoo, L.A. and R.H. Rautiainen, *A systematic review of farm safety interventions*. *American Journal of Preventive Medicine*, 2000. **18**(4S): p. 51-62.
13. Hartling, L., et al., *A systematic review of interventions to prevent childhood farm injuries*. *Pediatrics*, 2004. **114**(5): p. e483-e496.
14. Gadomski, A., et al., *Efficacy of the North American guidelines for children's agricultural tasks in reducing childhood agricultural injuries*. *American Journal of Public Health*, 2006. **96**(4): p. 722-727.
15. Kidd, P., et al., *The transtheoretical model of change in adolescents: Implications of injury prevention*. *Journal of Safety Research*, 2003. **34**(3): p. 281-288.
16. Lee, B.C., J.D. Westaby, and R.L. Berg, *Impact of a national rural youth health and safety initiative: Results from a randomized controlled trial*. *American Journal of Public Health*, 2004. **94**(10): p. 1743-1749.
17. Liller, K.D. and I. Pintado, *Kids and communities count: Reaching migrant children and families with the North American Guidelines for Children's Agricultural Tasks (NAGCAT)*. *Journal of Agricultural Safety and Health*, 2005. **11**(3): p. 365-372.
18. Marlenga, B., et al., *Changing the child labor laws for agriculture: Impact on injury*. *American Journal of Public Health*, 2007. **97**(2): p. 276-282.

19. McCallum, D.M., et al., *Safety-related knowledge and behaviour changes in participants of farm safety day camps*. Journal of Agricultural Safety and Health, 2005. **11**(1): p. 35-50.
20. Reed, D.B., S.C. Westneat, and P. Kidd, *Observation study of students who completed a high school agricultural safety education program*. Journal of Agricultural Safety and Health, 2003. **9**(4): p. 275-283.
21. Reed, D.B. and P.S. Kidd, *Collaboration between nurses and agricultural teachers to prevent adolescent agricultural injuries: The agricultural disability awareness and risk education model*. Public Health Nursing, 2004. **21**(4): p. 323-330.
22. Chapman, L.J., et al., *Evaluation of an intervention to reduce musculoskeletal hazards among fresh market vegetable growers*. Applied Ergonomics, 2004. **35**(1): p. 57-66.
23. Chapman, L.J., et al., *Evaluation of an occupational injury intervention among Wisconsin dairy farmers*. Journal of Agricultural Safety and Health, 2003. **9**(3): p. 197-209.
24. Heikkonen, J. and V. Louhevaara, *Empowerment in farmers' occupational health services*. Annals of Agricultural and Environmental Medicine, 2003. **10**(1): p. 45-52.
25. Legault, M.L. and D.J. Murphy, *Evaluation of the agricultural safety health best management practices manual*. Journal of Agricultural Safety and Health, 2000. **6**(2): p. 141-153.
26. Perry, M.J. and P.M. Layde, *Farm pesticides: Outcomes of a randomized controlled intervention to reduce risks*. American Journal of Preventive Medicine, 2003. **24**(4): p. 310-315.
27. Stave, C., M. Torner, and M. Eklof, *An intervention method for occupational safety in farming - evaluation of the effect and process*. Applied Ergonomics, 2007. **38**(3): p. 357-368.
28. Vela Acosta, M.S., et al., *Measuring success in a pesticide risk reduction program among migrant farmworkers in Colorado*. American Journal of Industrial Medicine, 2005. **47**(3): p. 237-245.
29. Palmberg, L., et al., *Partial protection by respirators on airways responses following exposure in a swine house*. American Journal of Industrial Medicine, 2004. **46**(4): p. 363-370.
30. Stone, J.F., et al., *Protective headgear for Midwestern agriculture: A limited wear study*. Journal of Environmental Health, 2001. **63**(7): p. 13-19.
31. Hallman, E.M., *ROPS retrofitting: Measuring effectiveness of incentives and uncovering inherent barriers to success*. Journal of Agricultural Safety and Health, 2005. **11**(1): p. 75-84.
32. Myers, M.L., H.P. Cole, and S.C. Westneat, *Seatbelt use during tractor overturns*. Journal of Agricultural Safety and Health, 2006. **12**(1): p. 43-49.
33. Earle-Richardson, G., et al., *Orchard evaluation of ergonomically modified apple bucket*. Journal of Agromedicine, 2006. **11**(3/4): p.??
34. Gregory, D.E., S. Milosavljevic, and J.P. Callaghan, *Quantifying low back peak and cumulative loads in open and senior sheep shearers in New Zealand: Examining the effects of a trunk harness*. Ergonomics, 2006. **49**(10): p. 968-981.
35. Milosavljevic, S., et al., *The influence of a back support harness on spinal forces during sheep shearing*. Ergonomics, 2004. **47**(11): p. 1208-1225.
36. Southard, S.A., et al., *Ergonomic interventions for the reduction of back and shoulder biomechanical loading when weighing calves*. International Journal of Industrial Ergonomics, 2007. **37**(2): p. 103-110.
37. Stal, M., S. Pinzke, and G.-A. Hansson, *The effect on workload by using a support arm in parlour milking*. International Journal of Industrial Ergonomics, 2003. **32**(2): p. 121-132.

38. Jenkins, P.L., et al., *Screening events to reduce farmers' hazardous exposures*. Journal of Agricultural Safety and Health, 2007. **13**(1): p. 57-64.
39. Rydholm, L. and S.R. Kirkhorn, *A study of the impact and efficacy of health fairs for farmers*. Journal of Agricultural Safety and Health, 2005. **11**(4): p. 441-448.
40. Forst, L., et al., *Effectiveness of community health workers for promoting use of safety eyewear by Latino farm workers*. American Journal of Industrial Medicine, 2004. **46**(6): p. 607-613.
41. Mandel, J.H., et al., *Safe handling of agricultural pesticides in Minnesota: Results of a country-wide educational intervention*. Journal of Rural Health, 2000. **16**(2): p. 148-154.
42. Rasmussen, K., et al., *Prevention of farm injuries in Denmark*. Scandinavian Journal of Work, Environment and Health, 2003. **29**(4): p. 288-296.
43. Rautiainen, R.H., et al., *Injuries in the Iowa certified farm study*. Journal of Agricultural Safety and Health, 2004. **10**(1): p. 51-63.
44. Faucett, J., et al., *Rest break interventions in stoop labor tasks*. Applied Ergonomics, 2007. **38**(2): p. 219-226.
45. Rautiainen, R.H., et al., *Effects of premium discount on workers' compensation claims in agriculture in Finland*. American Journal of Industrial Medicine, 2005. **48**(2): p. 100-109.
46. Gadowski, A.M., et al., *Preventing farm injury: A randomized field trial of the North American Guidelines for Childhood/ Agricultural Injury Prevention (NAGCAT)*. Pediatric Research, 2004. **55**(4): p. 22A.
47. Marlunga, B., et al., *Evaluation of a policy to reduce youth tractor crashes on public roads*. Injury Prevention, 2006. **12**: p. 46-51.
48. Liller, K.D., et al., *Development and evaluation of the Kids Count Farm Safety lesson*. Journal of Agricultural Safety and Health, 2002. **8**(4): p. 411-421.
49. Robson, L.S., et al., *Guide to evaluating the effectiveness of strategies for preventing work injuries: How to show whether a safety intervention works*. 2001, CDC: Cincinnati, Ohio. p. 122.
50. Rautiainen, R.H., et al., *Interventions for preventing injuries in the agricultural industry*, in *The Cochrane Database of Systematic Reviews*. 2008.
51. Darrington, M. *Child safe play area project*. in *6th National Farm Health and Safety Conference*. 2007. Adelaide, South Australia.
52. Keifer, M.C., *Effectiveness of intervention in reducing pesticide overexposure and poisonings*. American Journal of Preventive Medicine, 2000. **18**(4S): p. 80-89.
53. Lower, T., I. Ellis, and A. Larson, *Reducing All Terrain Vehicle injury: A randomised controlled study of driver training*. 2005, Rural Industries Research and Development Corporation.
54. Holmberg, S., et al., *The impact of physical work exposure on musculoskeletal symptoms among farmers and rural non-farmers*. Annals of Agricultural and Environmental Medicine, 2003. **10**(2): p. 179-184.