OCCUPATIONAL INJURY AND DISEASE IN AGRICULTURE IN NORTH AMERICA, EUROPE AND AUSTRALASIA:

A REVIEW OF THE LITERATURE

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ABBREVIATIONS

ATV	All Terrain Vehicle
CIs	Confidence Intervals
NIHL	Noise Induced Hearing Loss
LBP	Lower Back Pain
LD	Life time Days
MSC	Musculoskeletal Condition
MSD	Musculoskeletal Disorder
NHL	Non-Hodgkin's Lymphoma
ORs	Odds Ratios
PPE	Personal Protective Equipment
RCD	Residual Current Device
RR	Rate Ratios

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INTRODUCTION

Occupational health in agriculture is a significant international public health issue. Agricultural workers and their families are vulnerable to high injury and fatality rates and exposures that increase the risk of certain diseases. In developed agricultural nations the burden of occupational injury and disease has raised concern amongst researchers, policy makers, community interest groups and governments alike. The research record highlights a number of specific issues relevant to developed agricultural practices that heighten or at least increase the risk of injury and disease; and a growing body of research addresses how effective interventions might be developed to reduce this burden of disease. Whilst the risk and exposures literature does not always provide conclusive results with respect to the nature of the relation between exposure and risk of injury and disease; it is clear that there continues to be concern about the most common mechanisms involved in injury; and exposures that might impact on the health of those working in the agricultural sector (McCurdy & Carroll 2000)

The aim of this review was to systematically identify and critically appraise epidemiological studies that have investigated risk factors contributing to agricultural injuries and occupational disease in North America, Europe and Australasia.

Summary:

- This review confirms the most common mechanisms for serious non-fatal injury and fatal injury include tractors, agricultural machinery (including vehicles), livestock and falls for all age groups, in all three regions under review.
- The exposures and risks of disease in the agricultural sector currently being researched and where researchers signal the need for further research involve: exposure to dust and organic materials and the relation to respiratory disorders; exposure to pesticides, herbicides and insecticides and associations with various cancers including: non-Hodgkin's lymphoma; prostate cancer, breast and ovarian cancer, leukaemia and multiple myeloma and brain cancers; and environmentally associated cancers, skin cancer and cancer of the lip and heightened risks by production practice.
- Occupational fatalities in agriculture remain high, despite decreases in other occupational fatality rates in all three regions over the last decade. The research shows that: men in all age groups; older workers/farmers; migrant and seasonal workers; youths (particularly those aged between 11-15 years and male) and children, in particular male children are particularly at risk of fatal injury. Intentional fatal injury (suicide) involves predominantly farm owners and managers, who are also predominantly men.

Methods

1.1 Search Strategy (data sources)

Electronic data bases searched included: Agricola, AMED, Medline, Scopus, Eric, Ambase and PsychINFO.

Keywords used included: Agriculture, rural, farm, injury, collision, fall, drown, suffocate, asphyxia, electrocute, acute poison, disease, respiratory, asthma, cancer, carcino, hear, vision or sight, pain, infection, musculoskeletal or MSD, depression or anxiety, injury or collision with all previously listed, risk factor, risk, hazard, rate, association, ATV, 4WD, 2WD or AWD, motor or motor vehicle, all terrain, or terrain, or off road, PTO or power take off or power, tractor, predict, machine, sleep, fatigue, stress, observation studies, observational studies (MeSH), cohort studies, cohort studies (MeSH), case control studies, case control studies (MeSH), Cross sectional studies, cross sectional studies (MeSH), follow up studies, follow up studies (MeSH).

The search was limited to publications from 2000 to 2008 and for the following study designs: cohort, case-control, cross-sectional, prevalence surveys, case-series, surveillance data and analyses of routine data. In addition, studies were required to address not only prevalence, but also risk, exposure and outcome. Reference lists of included studies were searched for additional relevant studies. The search and inclusion was limited to English language only.

Major injury journals published between 2000 and 2008 were also searched. These included: Injury Prevention, Accident Analysis and Prevention, Injury, Journal of Safety Research, Injury Control and Safety Promotion.

Specific rural journals searched included, Journal of Agricultural Health and Safety, Journal of Rural Health, Australian Journal of Rural Health. Specialist journals searched included: Applied Ergonomics, American Journal of Industrial Medicine, Ergonomics, Journal of Biomechanics, Journal of Occupational and Environmental Medicine, Journal of Safety Science, Occupational and Environmental Medicine, Scandinavian Journal of Work and Environment.

1.2 Inclusion criteria

Studies were included in this review if they specifically considered agricultural related injuries, diseases or deaths as an outcome, measured any potential risk factor for occupation related exposure to injury and disease and if they were written in English. Many studies considered known risk factors, but only those that considered these risk factors in relation to the occurrence of injury and or disease or death were included. Studies had to have been published in and after 2000 and up until June 2008.

1.3 Outcome measures

Injury was defined as any event that required medical attention or resulted in time off from usual activities. Farm-related injuries are those injuries that occurred on the farm and were a result of an event related to agricultural production.

2.0 Results

The data base searches located over 400 papers. Restricting this search to English language and specified epidemiological study designs (cohort and other longitudinal, case control, cross sectional, prevalence surveys, case-series, surveillance data and analyses of routine data) reduced the number of studies to 210 for consideration. Abstracts from each of these were considered for eligibility and the full texts were then appraised.

Key reviews from 2000 until 2007 were also appraised.

2.1 Fatal and non-fatal injury – risks, exposure and prevalence:

A total of 215 papers met the inclusion criteria and were included in this review. Table 1 (Appendix A) provides a summary of the literature on agricultural injury and disease by study designs. Eighty three papers addressing injury risk and exposure were included for review. Of these, 17 were cohort studies, with 15 conducted in the United States and 2 in Europe, with none in Australasia. 18 were cross sectional surveys, with 12 conducted in North America, 2 in Europe, 2 in Australia and 2 in New Zealand. 41 studies involved the analysis of routine data, of which 25 analysed data sets in North America, 5 in Europe, 6 in Australia and 5 in New Zealand. There were 5 case series studies, 3 conducted in North America and 2 in Australia. There were 10 prevalence surveys, 8 conducted in North America, 1 in Australia and 1 in Europe (the United Kingdom). Finally, there were 5 on-site observational studies, 4 in North America and 1 in New Zealand.

2.2 Disease in agriculture – risks, exposures and prevalence

A total of 119 papers addressing risk factors and exposures associated with occupational disease in agriculture were included for review; these studies are summarized in Table 2 (Appendix B) by study design and disease or condition. There were 37 cohort studies, 26 case control studies, 39 cross-sectional studies, one case series study and 16 analyses of routine data.

3.0 The agricultural populations under consideration in this review

In this period the majority of research that has been conducted in the North America, Europe and Australasia has tended to focus on agricultural populations consisting of predominantly family farmers (also noted by: McCurdy & Carroll 2000 for the literature prior to 2000). Studies focussing on injury on farms that are not family owned or operated (or primarily dependent on family labour) are less common in all three regions. Studies of disease in agriculture are more likely to have samples that draw from all labour composition and ownership types in agriculture, in all three regions.

Whilst there are strong commonalities in agricultural productive practices, mechanisms, injury type and rates, and exposures associated with occupational injury and disease between these regions, there are also important differences in the nature of agricultural practices (largely determined by climatic differences) and the agricultural labour force that work on family farms and or larger productive units.

Specifically, in Europe and North America housing livestock is common, whereas in Australasia the more temperate climate ensures outdoor grazing all year. Droughts are common to all regions and this has implications in terms of labour practices and use of certain machinery/mechanisms that are implicated in injury risk and in some instances intentional fatal injury (suicide rates). There are important differences in the labour force, temporary migrant labour is substantially more prevalent in both North America (involving approximately 900 000 workers (McCurdy & Carroll 2000) and Europe bringing with it different and at times increased risks with respect to occupational injury and disease in this sector. Australia and New Zealand; whilst having a history of seasonal labour in this sector are only now actively seeking migrant labour to meet labour shortages in agriculture. It is, however, too early to ascertain how this will impact on occupational injury and disease prevalence rates or what the nature of risk and exposure might be for this changing, temporary and mobile labour force (Lovelock and Leopold 2009).

Additionally, important socio-demographic differences exist between farm owners, farm managers, farm workers (and local workers versus migrant workers); family farmers and corporate farms both within these regions and between these regions. While overviews of the agricultural population can be found in injury reviews focusing on the United States (for instance McCurdy and Carroll, 2000) they are less common in reviews focusing on Canada, Europe and Australasia and since 2000 none have been included in publications found in this search on injury and disease in agriculture. The literature in the following review is entirely quantitative, most of these studies collect socio-demographic information for the population under consideration, most do not situate this in relation to the broader socio-demographic realities of the region within which this sub-population works and resides. Further the literature also characteristically does not consider the social determinants of injury and disease, beyond documenting mechanisms of injury and exposure risks; and thus largely precludes any discussion of what, why and how social and cultural processes shape exposure and risk and ultimately injury and disease outcomes for these populations. To provide an in-depth consideration of the socio-demographic features that undoubtedly shape the social determinants of injury and disease in these regions is not only beyond the scope of this review but would be hampered by a dearth of available research in this field that considers these factors in part or comprehensively.[1]

It is nonetheless necessary to briefly outline the nature of the populations under consideration in order to situate the results of the research outlined and discussed in this review.

3.1 The United States

The agricultural population in the United States includes farmers, hired farm labour, temporary migrant workers and on family farms – family labour, including the labour of children. In 1997 3, 352 028 people worked on US farms (cited in McCurdy & Carroll 2000; statistics from the Census of Agriculture 1997). Most family farmers are white, US born, well educated and economically "well-off" (Schenker, cited in McCurdy & Carroll 2000).

[1] With respect to the Effective Interventions in Occupational Health in Agriculture study, the Stakeholder report is based on qualitative research that attempts to address the socio-cultural factors that shape injury and disease outcomes in agriculture in New Zealand.

Most farm operators are aged between 50-55 years, whereas hired farm workers, in contrast to operators, are predominantly Hispanic, foreign born, have low educational and socio-economic status and are also young, on average between 25-34 years of age. The actual number of hired farm workers has been inadequately enumerated in the US as it excludes contract labourers and those farms that employ less than 11 workers. It has been estimated that the number of hired farm labourers is approximately 2.5 million, with 2 million being engaged in crop production (Martin and Martin 1994). Farm workers incomes are low, with approximately 60% of farm workers living in poverty (Mehta et al 2000 cited in McCurdy & Carroll 2000). Undocumented migrant labour is a significant issue in this sector and these workers are likely to be remunerated at even lower levels; injury and disease amongst these workers is undocumented. More generally however, of the documented ethnic minority groups working in agriculture, all have higher risks for farm injury death (Richardson et al 1997; Lyman et al 1999).

3.2 Canada

A consolidation of farms in Canada has driven declining employment in this sector. There are approximately 346 200 farm operators and a farm population (those living on farms in households with a farm operator) of 684 260 (Statistics Canada 2006). Those working in agriculture include: full time workers, part time workers, causal workers, temporary migrant workers (primarily from Mexico), family labour on family farms, including the labour of children. While employment in this sector has been declining there have been shortages in local labour and Canada has been actively recruiting temporary migrants to meet labour shortages (Immigration Canada 2008). The total number of farms is 229 373 in 2006, down from 293 089 in 1986 (Statistics Canada 2006). The total land area in farming is 41 377 673 hectares, with 194 717 farms with land in crops. Ranching (including those with feedlots[2]) and grain farming are the dominant production types. Seventy nine percent of the operators are Canadian born. The labour force is ethnically diverse with European migrants being the dominant group (Eastern, Western and Southern), followed by migrants from the United Kingdom and the United States. Amongst the visible minority groups are migrants from, India, Peoples Republic of China, and Mexico, with these groups comprising between 0.2 and 2.2 of the total labour force working in agriculture. Fatal and non-fatal injury rates in agriculture in Canada are disproportionately high. The overall annual rate of 11.6% deaths per 100 000, farm population ranks farming as the fourth most risky occupation in Canada (Locker et al 2002).

3.3 Europe

An account is only provided for those countries where research has been published in the period of this review: the United Kingdom, France, Germany, Norway, Poland, Spain, Turkey and Greece. Similar to Canada and the United States the labour composition of those working in agriculture in Europe includes farm owners, agricultural labourers, temporary and seasonal migrant workers with a decline in the number of people working in agriculture observed in all Western European countries over the last two decades.

[2] Crops grown to feed stock.

In the United Kingdom approximately 77% of the total land area is in agricultural production with the agricultural labour force comprising approximately 1.4% of the total labour force. There are approximately 526 000 workers in agriculture, including part time, full time and casual workers. There are approximately 300 000 farms with an average size of 57 hectares, which is larger than the European average farm size of approximately 20 hectares. Of those farms that are larger than 100 hectares, the majority are in Scotland. These larger farms account for approximately 65% of the total agricultural area. The main production includes cereals, oilseeds, potatoes, vegetables, cattle, sheep, poultry and dairy. As elsewhere in Europe there has been a decline in the number of full time jobs in agriculture and a trend toward employing temporary seasonal labour from abroad. These temporary migrant workers come primarily from Estonia, Hungary, Latvia, Lithuania, Poland, Slovakia and Slovenia and Portugal. Agricultural production is highly mechanised in the United Kingdom and agricultural workers have similar occupational health issues to those in North America.

Unlike Canada and the United States some of the European countries included in this review are also substantial importers of agricultural produce, for example Germany. In the Western area of Germany there has been a significant decline in the number of farms in the post WWII period, with increased mechanisation and productivity resulting in many farmers leaving farming and taking employment in both the industrial and service sectors, where they can also earn better incomes. The agricultural workforce in Germany comprises three percent of the total workforce. In the Western states of Germany farms are predominantly family owned and are small holdings. In contrast, in the Eastern area 80% of the German agricultural output is produced. Dairy, pork, beef, poultry, cereals, potatoes, cabbage, sugar beets, wheat and barley comprise the productive output of the agricultural sector and 34% of the land area in eastern Germany is in crop production.

In France there are approximately 730 000 farms employing approximately 7% of the workforce. This agricultural labour force is aging as increasing numbers of young people seek work in urban centres, in industry and in service occupations. Increasing mechanisation in the post WW II period has also led to increased production and a reduction in the labour required on farms. The French produce cereal crops, beef, pork, poultry, fruit, vegetables and wine and while self sufficient in food supplies they also import refined agricultural products. Almost half of the agricultural income is generated through livestock farming with the other half largely being met through crop farming.

In Norway agricultural production accounts for approximately 2% of the annual GDP and involves approximately 3% of the land area. Farms are typically small and family owned and owners often take other work outside of farming to subsidise their income. Forestry and fishing often serve as the secondary occupation. There has been some farm consolidation since the 1950s. In the South farms are larger and various grains are produced, livestock and dairying are more typical of the east of Norway. As elsewhere in Europe it has become increasingly difficult to attract and or retain young people in rural areas and labour shortages are common. In order to meet seasonal labour demands between 15 to 20,000 foreign workers come into Norway on temporary permits annually, mainly from Poland, Lithuania, Latvia and Estonia.

Poland, Spain, Turkey and Greece

Whilst these countries are vastly different in many respects they have been placed together for the purposes of this review, primarily because they share similar agricultural development issues, where agriculture is still largely labour intensive and all four countries have been comparatively slow to mechanise their production processes. Some of the specific characteristics will be briefly outlined here, but this is by no means a comprehensive account of the context for agriculture in these countries. In Poland approximately one in every four people is engaged in agricultural production. The incidence of injury is high, with 29.3/100 000 incidences for those employed in agriculture and where fatal trauma in agriculture accounts for 33.6% of all accidents workplaces in Poland. Farming is generally small scale and family operated, with low productivity, little mechanisation and land lots that are often fragmented and dispersed. There has been little and in some areas no land consolidation.

In Spain, approximately forty percent of the land area is suitable for cultivation, although only ten percent of this area is described as rich and fertile land. The rough terrain has been an impediment to mechanisation and the type of land holding usually fits one of two extremes, either a large estate or a very small holding. Livestock accounts for approximately 30% of all agricultural production and grains, citrus fruits, poultry and dairy account for the other dominant products. Modernisation of agriculture has been slow, however since the 1970s there has been considerable outward migration from rural areas and increasingly Spain relies on seasonal, temporary migrant labour, primarily from the Maghreb countries of North Africa to meet agricultural labour demands (Ostergren & Rice 2004). The labour shortages in agriculture have encouraged many of the large estate owners to mechanise. Since the 1960s when the labour force accounted for 42% of the total labour force, fewer people are now engaged in agricultural production in a full time capacity, fewer young people are interested in working in agriculture and the current agricultural labour force accounts for approximately 13% of the total. Government intervention as a consequence of outward rural migration has led to some land consolidation of smaller lots.

In Turkey, 11.2% of the labour force is engaged in agricultural production. Whilst a newly industrialised country, less emphasis has been placed on industrialising agriculture and most in the agricultural sector have been slow to respond to new technologies and overall mechanisation has been limited. While self sufficient in food production, this production is still largely dependent on small lot farmers, family labour and people working on small and non-contiguous plots. Crop production accounts for two thirds of agricultural outputs and livestock the remaining third.

In Greece there are approximately 528 000 farmers representing approximately 12 percent of the total labour force. The farms are typically small in size, family owned and operated and are heavily subsidised by the government. There has been an increase in modern farming methods, but generally mechanisation has been slow and production levels are low. The dominant farming types include crops, livestock, fruit and vegetables. Consistent with other European countries the agricultural labour force is aging with young people being less interested in taking up agricultural employment.

Overall, in the EU, amongst the pre-enlargement fifteen member states there has been a trend toward fewer full time jobs in agriculture, where 13 million full time workers in agriculture in 1970 had dropped to 7 million full time jobs by 2004. There has been an increasing reliance on temporary seasonal workers, many of whom are foreign temporary migrants.

3.5 Australia

In Australia there were approximately 128 500 businesses engaged in agricultural operations reporting an estimated value of agricultural output of $5 000 or more, in 2005 (ABS, 2007). Although the total number of agricultural businesses has declined by 25% in the last 25 years (Larson,2002). The total farm size is increasing, indicating consolidation of smaller farms into larger farming units. The main agricultural business engagement is beef cattle farming, mixed grain/sheep/beef farming, sheep farming, grain growing or dairy cattle farming. Employment in the agricultural sector has also declined considerably (ABS 2007). Reductions in the agricultural workforce have been observed since 2003 and are largely a result of a prolonged, severe drought experienced across Australia. There has also been a significant departure of farming families (where both spouses/partners indicate their main occupation is farming) from agriculture with a decline of 31 800 (22%) families in the 15 years to 2001 (ABS, 2003). Reasons for leaving agriculture include personal, economic and environmental pressures. There is also a trend for Australian farming families to obtain off-farm income to maintain their standard of living and for the farming operation to remain financially viable (ABS, 2003). In broad acre and dairying farming, the spouse (mostly women) were more likely than owner-managers to participate in off-farm employment (29% versus 17%) (ABARE, 2003). The median age of farmers in farming families was 51 years in 2001, with 15% of farmers aged 65 years and over (ABS, 2003). Overall, farmers in Australia are aging, partnering at a later age and fewer young people are becoming farmers (ABS, 2003).

Migrant labour is employed for seasonal harvesting and as elsewhere has been sought to overcome chronic labour shortages in this sector. Australian labour force data indicates that migrants make up 10.6% of the labour force in agriculture, forestry and fishery (ABS unpublished statistics, 2001). In August 2008 Australia initiated a Pacific “Guest Worker” scheme to temporarily employ workers from Papua New Guinea and other Pacific nations to address seasonal labour needs. The development, nature and scope of this scheme relied heavily on the Recognised Seasonal Employer Policy introduced in New Zealand in 2007.

There are a number of significant health and safety concerns on Australian farms. Australian farmers and farm workers have higher than average death rates with regards to fatal injury, road traffic injury, suicide, cardiovascular disease and for certain cancers (Fragar & Franklin, 2000).

Climate change remains a pressing issue for Australian farmers, with Australia predicted to be the most adversely affected by climate change out of all of the global agricultural regions (Gunasekera et. al., 2007). Predictions of significant reductions in rainfall across many farming regions of Australia have been made and come on the back of a severe, prolonged drought which has already resulted in reduced agricultural productivity.

3.6 New Zealand.

There are approximately 40 000 farms in New Zealand (productive land that returns more than $40 000 New Zealand dollars per annum (Agricultural Census)). The agricultural labour force comprises approximately 103 000 people, including full time, part time, casual and seasonal workers (Department of Statistics). Hidden from these statistics is the labour provided unpaid by family members, including children. Most farm operators (owners, decision makers, managers) are white, have relatively high education levels, and on average earn above average incomes (Agricultural Census). Historically Maori had high participation rates working in agriculture, but with urban migration their rate of participation has decline dramatically (LeHeron 1998) In addition there are approximately 5000 temporary migrant workers working in agriculture, most of whom come from the Pacific Islands and are recruited through The Recognised Seasonal Employer policy introduced in 2007 to address labour shortages in this sector (Lovelock and Leopold 2009). Until the introduction of this scheme it has been estimated that 80% of producers engaged in crop/horticulture production sought and employed undocumented (illegal) migrants (Lovelock & Leopold 2009). There are also other temporary migrant workers, working in agriculture, however, for these workers it is not the express purpose of their working visas. These workers are predominantly from Germany and the United Kingdom. All are remunerated in accordance with national labour legislation and are entitled to medical care and compensation for occupational injury through the state accident compensation scheme. The agricultural workforce experiences high levels of mortality and morbidity. In the decade 1985-94 the annual work related fatal injury rate in agricultural occupations in New Zealand was 21/100 000, four times the all industry average (Cryer 1989; Marshall et al 1996; Horsburgh 2001; Feyer et al 2001). The primary agents for fatal and non-fatal injury on farms in New Zealand are agricultural machinery, specifically, tractors, all terrain vehicles and animals, in particular horse, sheep and cattle.

In the last decade there has been evidence of farm consolidation, a decrease in farms and increasing in size of holdings (McLeod & Moller 2006). There has also been some evidence of encroachment on productive land with an increase in the number of lifestyle lots with limited if no productive output, particularly around urban centres (McLeod & Moller 2006). There have been changes in production in the last decade, with an increase in dairying production, declining participation in wool production, particularly in the last five years, and increased conversion of pastoral land into viticultural and horticultural production in some regions (Agricultural Census 2006). All of these shifts have implications for the labour force and in turn implications with respect to risks of injury facing this labour force (McLeod & Moller 2006; Lovelock and Leopold 2009).

The majority of farms in New Zealand are family operated (owned either by families or by Trusts or various other legal entities and combinations). There are a number of corporate farms with many of these in the last decade engaged in dairy production, operating large landholdings and running large herds (1000 or more cows). In addition they often have overseas capital investment/ and or are foreign owned (Le Heron & Pawson 1996, pers.com 2008). To-date there is no research that has explored and compared fatal or non fatal injury rates on family or corporate farms, two vastly different employment situations.

Agricultural production in a temperate country such as New Zealand ensures there is no need to house animals indoors in the winter months. Thus agricultural workers in New Zealand are largely not exposed to high levels of dust and or organic particles, unlike agricultural workers in less temperate zones where housing animals indoors is a necessity for most of the winter months and where workers face a greater risk of respiratory conditions.

4.0 Structure of the Report

This report is divided into two parts. The first part addresses the literature on injury in agriculture and the second part addresses the literature on disease in agriculture. Both Part One and Part Two present the literature in terms of key socio-demographic characteristics of the agricultural population, mechanisms of injury and associations of various agricultural practices and products with injury and disease outcomes. As many of the studies address a number of issues and provide results that cover a range of people in agriculture and a range of outcomes some of these studies are mentioned more than once in a number of sections throughout the report. Each section has a summary and the literature for both Part One and Part Two are summarised in table form and can be found in Appendix A (Study designs) Appendix B (Injury) Appendix C (Disease). The summaries at the end of Part One and Part Two address the key findings and the methodological limitations in the area and presents the review's key conclusions and recommendations.

5.0 Part One: Epidemiologic studies of fatal and non-fatal injury in agriculture

Table One summarises the literature published between 2000-2008 on injury risk, exposure and outcomes in agriculture and can be found in Appendix A.

5.1 Age:

The review reveals that risk, exposure and injury outcome varies according to age and age group. Some age groups are more at risk and have more serious injury outcomes than others. Children, youths (11-20), and older people are at greater risk of serious injury in all three regions.

The search on children (0-11 years) and agricultural injury found 1 cohort study as well as 14 analyses of routine data sets; this research is summarized below and then followed by a more detailed account of the studies.

5.2 Summary of studies on pre-school children and fatal and non-fatal injury in all three regions

- Research in North America revealed that children were at risk of fatal and non-fatal injury from machinery (Liller & Lehtola 2000; Meiers 2001; Pickett et al 2007, Pickett et al 2005) vehicles including tractors and utilities (Meiers 2001; Mason 2002; Pickett et al 2007; Pickett et al 2005; Little et al 2003); ATVs (Little et al 2003, Shaults 2005); falls and livestock (Hubler 2002; Pickett et al 2005) and firearms (Little et al 2003). Preschool children were found to be at risk of drownings in Canada and the United States (Pickett et al 2005, Brison 2006). With some research finding that boys were more at risk than girls (Hubler 2002, Brison 2006). In addition, children were found to be more at risk if maternal age was less than 25 years and where there were two or more children in the family (Flower et al 2006). Children were also noted to be more at risk in spring and summer and on weekends (Little et al 2003). Performing tasks that were not age appropriate or beyond their developmental ability was also related to fatal and non-fatal injury in children (Mason 2002). In the United States and Canada bystander and passenger vehicle run-overs were a significant cause of fatal injury for children (Pickett et al 2005, Brison 2006); as was riding as an extra passenger (Pickett et al 2007. Horse related fatal and non-fatal injury was more common for girls (Pickett et al 2007). Another study in the United States explored emergency department pediatric ATV injuries in West Central Illinois. Researchers concluded the incidence of ATV related injury is increasing (Nelson et al 2005). Children were overly represented in fatalities relating to grain storage bins, in a study conducted in the United States (Kingman et al 2001).
- Research in Europe revealed that children were at risk of hand injuries with poor outcomes from agricultural machinery and engine belts (Terziloglu 2004). Tractors and farm machinery were also key mechanisms of injury for children in the United Kingdom (Meiers 2001).

- Research in Australia revealed that children under the age of six were at risk of fatal-injury from drowning (Bugela and Franklin 2005; Mitchell et al 2001). Some research has established seasonal variation where children were more at risk in spring and summer and on weekends (Bugela & Franklin 2005). Children under five years of age were also at risk of injuries from tractors and utilities (Mitchell et al 2001).
- In New Zealand, children accounted for 45% of New Zealand's total workplace bystander deaths (Lilley 2004).

5.3 The studies

A cohort study of children in Iowa and North Carolina revealed increased agricultural machinery mortality amongst children in Iowa and an increased risk for children which was associated with maternal age (less than 25 years) and if there were two or more children in the family (Flower et al 2006).

Researchers analysed a routine data set with records of fatal drowning in dams for 27 children aged 0 to 5 years in rural Australia. These fatalities occurred predominantly in spring/summer and on weekends and more often amongst males less than 24 months old; in dams within 300 metres of the home and parental property; and in dams with inadequate fencing (Bugela & Franklin 2005).

The Hubler (2002) study of Amish children in the USA presenting to a hospital over a five month period identified 89 injuries and five fatalities. Male children sustained 64 injuries and female children 25 injuries. Falls were the most common mechanism of injury, followed by incidents involving livestock. Both incidents most commonly resulted in orthopaedic surgery.

A case series study of emergency department pediatric admissions for ATV related injuries was conducted in Illinois. The researchers concluded that ATV related injuries in Illinois are increasing and that these results mirror national trends (Nelson et al 2005).

An analysis of fatal injury data for farmer and farm workers in Florida, in the period 1989-1998, revealed there were 231 deaths, 20 deaths were children and 211 deaths were adults. The leading cause of death was machinery for both children and adults (Liller & Lehtola, 2000).

A study of workplace and work related fatal injury data in the period 1985-1998 in New Zealand explored fatality for children. The majority of children were fatally injured while a bystander to another person working. A third of all fatalities occurred within the agricultural industry and in the period 1985-1994 children less than 15 years of age accounted for 46% of New Zealand's total workplace bystander deaths (Lilley et al 2004).

Little et al (2003) analysed 1832 paediatric trauma cases in the United States and found 94 cases were children with farm related injuries. The mean age was 10.75 years and the mean Injury Severity Score (ISS) was 7.38. Three children died from their injuries while only four of the children wore protective equipment. There was seasonal and weekday variation with most of the injuries occurring in summer, 31% in spring and 55% on weekends. The average

time was 39 minutes to clinical presentation, 177 minutes before transfer to a trauma centre with 72 of the 94 children being admitted to hospital for treatment where the length of stay (LOS) was between 0-28 days with the mean 2.76 days. Twenty-eight percent (28%) of the children required surgery; 52% of the injuries were dislocations/fractures; 38% were lacerations and avulsions, 31% of the injuries were concussions, 30% contusions and 14% burns. The percentages amount to more than 100% as some individuals presented with more than one type of injury. The mechanisms of injury included: animals (41%); falls (34%); motor vehicles (28%); all terrain vehicles (20%); and firearms (4%).

An analysis of fatal and non-fatal injury data for children and youths aged 1-18 years on New York (USA) farms revealed 164 injuries of which 29 were fatal, 18 were disabling and where 55% occurred while working. The leading injury mechanisms were tractor run-over (12); and overturns (11). Of those working, 35% were younger than the accepted and established age limits considered appropriate for the task being performed. The tasks included loading square bales, fieldwork trailed implements and feeding calves and most commonly involved injury to young victims. Injuries involving non-powered wagons had the highest frequency of under-aged victims (82%). These results lead the researchers to conclude that children on (New York) farms are being assigned tasks that are developmentally inappropriate (Mason 2002).

Meiers (2001) analysis of trauma centre referrals between 1989-1998 explored fatal and non-fatal injury amongst children and youth, revealing that 49 children, under 19 years of age were injured. The mean age was 7.3 years, with 14 of the 45 children (31%) fatally injured and a male to female ratio of 2:1. The mechanisms of injury were tractors (33%); animals (29%); other machinery (9%); falls (9%), burns (4%). Twelve of the deaths involved tractors or machinery. There was seasonal variation with June to October (summer to fall/autumn) being the most prevalent period. The hours of 1pm-6pm was also the most prevalent time period for injury with 9 of the fatalities being supervised at the time of injury. Injuries included: orthopaedic (56%); neurologic (42%); and thoracoabdominal (22%); with thirteen percent (13%) of the survived injuries resulting in long term disability and seven (7) of the fatalities resulting from solitary head injuries. The average transport time to rural hospital was 1.5 hours, from hospital to trauma centre 2.3 hours, with two victims dying on route.

Mitchell et al (2001) analysed routine data that documented fatal injury amongst children in the period 1989-1992 in Australia and revealed an average of 29 deaths per year. Males were more commonly injured than females and children aged less than five years represented the majority of injury cases. The most common location for injury included dams and bodies of water, and where the cause of death was drowning. Other common mechanisms were tractors and utilities.

An analysis of child non-work related injuries in Canada and the United States revealed 370 cases of fatal and non-fatal injury amongst children. Children were mainly residents on farms (63%) and under the age of seven. The leading mechanisms for injury were bystander and passenger run-overs (fatalities); drowning (fatalities); machinery entanglements (hospitalizations); falls from heights (hospitalizations); and animal trauma (hospitalizations

and restricted activities injuries). Activities involved playing in the worksite; the child being a bystander or extra rider on farm machinery and recreational horseback riding (Pickett et al 2005).

Pickett et al (2007) investigated fatal and non-fatal cases of injury in children reviewing administrative data bases in Canada and the United States. They found 484 paediatric fall injury cases accounting for 41% of the case series (484/1193). Twenty percent (20%) of the fall injuries were a result of falling into the path of a moving hazard and were defined as complex falls. Ninety-one percent (91%) of complex falls were related to farm production and sixty-one percent (61%) of complex falls from heights occurred when the children were not working. Fatalities and hospitalizations were overrepresented in complex falls.

An analysis of hospital admissions for ATV related injuries of children aged 15 years and under was undertaken by Shaults (2005) in the United States. In 2001-2003 it is estimated that 108 724 children aged 15 years and under were treated in hospital for non-fatal injuries sustained while riding ATVs. ATV related injuries increased by 25% in this period. Males aged between 11-15 years accounted for 52% of emergency department (ED) visits and hospitalizations among young riders. Children aged between 0-5 years were more likely to have facial injuries and older children were more likely to have trunk, leg or foot injuries. Fractures were the most common diagnosis (27% of ED visits; 45% of hospitalizations). Researchers noted that current legislation does not effectively address rising ATV related injuries. It is also possible that some of the hospital admissions included non-farm people (Shaults 2005).

Non-fatal injuries of children in Anatolia (Turkey) recorded in an administrative data base identified 58 cases of hand injuries to children aged between 3-7 (mean 4.5) caused by engine belts on agricultural vehicles. The most common injury involved digit and the third finger. The thumb was involved in the least number of cases. Surgery was performed for lacerations, tendon repair, fixation of fractures, grafting and local flaps and overall the outcome for these children was poor (Terziloglu 2004).

Brison et al (2006) reviewed fatal injuries for children in Canada for the period 1990 to 2001, drawing on an administrative data set. Fatal agricultural injury was substantially higher than that of all-cause, unintentional injury among Canadian children aged 1-6 years (14.9 v 8.7 per 100 000 person/years respectively). There was elevated fatal injury amongst boys. Seventy-three percent (73%) of the injuries occurred at the worksite and were the result of being run over by machinery as a bystander (29%), falling from a vehicle when travelling as an extra rider (22%), and asphyxia due to drowning (23%). Of all children, preschool children were at greatest risk of fatal injury.

A review of 96 children presenting to hospital for injury in the United States over a period of nine years revealed the following injury patterns. The children were aged between 6 weeks and 17 years. Five of the children died and one child was discharged with severe brain injury to a rehabilitation facility. Forty percent (40%) of the injuries were animal related. Amish children had an increased risk of horse-related injury (38.5%). Twelve percent (12.5%) of

the injuries were a consequence of falls from buildings or haylofts. The injuries resulting from these falls included 36.4% with head trauma and 24% with skull fracture (Smith et al 2004).

Kingman et al (2001) reviewed the Purdue University database to identify fatal entrapments in on-farm grain storage bins in the period 1966-1998. The fatalities were mainly in association with corn production, with the study also identifying fatalities in Canada – in Ontario. There were many more close calls or near misses documented. In those cases where the age of the victim was known 24% of the victims were aged between 3 and 15 years of age. Those younger than 16 suffocated primarily in June, while older victims suffocated in November, December, January, February and March. The high number of children dying in storage bins is cause of concern. Unloading grain was a significant high risk activity. Where gender was identified, males accounted for 96% of the fatalities.

5.4 Summary of studies: Children and Younger age groups: (8-19 years)

- Research in North America reveals significant associations between farm-work related injury and younger age (Sprince et al 2003) with the greatest risks associated with tractors, machinery, animals, falls; and burns between summer to fall/autumn and between the hours of 1pm-6pm (Meiers 2001). Researchers have noted excess agricultural machinery mortality amongst youth in Iowa (Flower et al 2006); and that male youth are most vulnerable (Beer et al 2007). Severe back pain amongst youth farm-workers was found to be related to work practices (Shipp et al 2007) and high risk behaviours were evident in association with non-work injury, rather than work related injury, amongst youth workers (Ascota et al 2007). High risk behaviours amongst male youth and failure to wear safety equipment was evident in one study and also that male youth were more likely to use safety equipment if it was recommended by a physician (Reed 2006). Sleep patterns were significantly associated with injuries in one study (Stallones et al 2006). A study in Kentucky documented tractor use and found children to be operating tractors on public roads without ROPS and carrying extra riders to be common (Browning et al 2001). Another study in the United States explored the physical demands of working on the farm for children and low-back injury risk (Allread et al 2004). Another study in the United States considered musculoskeletal discomfort, injuries and work tasks performed by children and adolescents in Wisconsin fresh vegetable production. Fifty percent of the adolescents reported lower back pain and 25% reported disabling discomfort (Chapman et al 2003). Another study explored farm related limb amputations in children, all of the 12 children were “in the vicinity” but not operating machinery (McClure et al 2005).

- Youth make up 50% of all drive line related injuries (from augers, elevators, conveyers and machines) in the United States and are more likely to be injured in the autumn. Youth are also at high risk of ATV fatal and non-fatal injury, most commonly when used recreationally and when used with no safety gear and when riding ATV’s that are too large for them (Goldcamp et al 2006). The most common mechanisms associated with fatal injury are machinery, motor-vehicle, drowning, suicide and homicides (Myers 2001) and youth (under 16 years) represent just under half of the fatalities on farms (Goldcamp et al 2004). Two studies found that tractor overturns were most commonly associated with fatality and that youth had higher

rates of work related deaths when compared to all youth in other occupations (by a factor of 3.6) (Hard et al 2002, Hard et al 2006).

- In the United States the crop production sector has injury rates for 15 year old workers that are six times that of injury rates amongst all 15 year old workers; and 15 year old workers in this sector also have the highest fatality rates (Hard 2006). In another study youth are overly represented in tractor crashes on public roads (Marlenga et al 2006) and on minority owned farms youth are also at high risk of fatal and non-fatal injury (Hendricks et al 2005). Handling horse and cattle was associated with risk of injury for youth and girls were more at risk of horse related (recreational) injury than boys, while boys are more at risk of cattle related injury whilst working (Hendricks et al 2001). On farm falls amongst youth less than 20 years old were assessed by researchers in the United States and youth were found to be at considerable risk (Hendricks et al 2004). In Canada, youth have high rates of non-machinery related injury in British Columbia, whereas non-machinery related injury rates in other regions in Canada are comparatively low (Saar et al 2006).
- Research in the United Kingdom reveals that youth have a high risk of injury from clipping cattle (Lindsay et al 2004). Youth in Greece are more likely to have non-traffic related injuries (Alexe et al 2003) and male youth in Poland are at greater risk of fatal and non-fatal injury in the summer months (Sosnowska 2007).
- In Australia researchers have found that rural youth are at greater risk of motor-cycle injury if they are self taught (Lower et al 2003) while the most common mechanisms of injury are drowning (Mitchell 2001) motor-vehicles and firearms (Mitchell 2002).

5.5 The studies:

In Iowa and North Carolina a cohort study of all age groups revealed excess agricultural machinery mortality amongst children in Iowa and an increased risk (for children) associated with maternal age (less than 25 years) and if there were two or more children (Flower et al 2006). A cohort study of 6999 farmers in Iowa identified 431 with injuries in the previous 12 months and 473 controls who had no injury in the previous 12 months. Significant associations were found between farm-work related injury and younger age (Sprince et al 2003).

A cohort study of 2 536 Texas high school students including both farm workers and non-farm workers considered self reported back pain resulting in more than four hours of time lost and or medical care, or pain lasting for more than one week. Sixteen percent (15.7%) of farm workers and twelve percent (12.4%) of non-farm workers reported severe back pain. Multivariate analysis for farm workers showed significantly increased adjusted odd ratios for severe back pain amongst females (OR4.59); those with prior back injury (OR9.04); those feeling tense, stressed or anxious (sometimes/often) (OR4.11); those lifting or carrying heavy objects while not at work (OR2.98); those with current tobacco use (OR2.79); those with 6+ years involved in migrant farm work (OR5.02); working with/around knives and those working on corn crops (OR3.87) (Shipp et al 2007).

A cross sectional study of 4 914 9th grade high school students in South Texas considered health risk behaviours and work and non-work related injury. An aggregate risk score (ARS)

was developed based on health risk behaviours. Mean ARS scores were significantly higher ($p<0.05$) for both male and female adolescents who reported a work related injury compared with non-working adolescents; and for males who had done migrant farm work when compared with other males who had not done migrant farm work. After controlling for confounders a statistically significant association between ARS and non-farm work related injury was found, but not between ARS and farm work related injury. Farm workers with high ARS scores were more likely to report non-farm work related injuries (Ascota et al 2007).

In another cross-sectional study researchers considered all injuries relating to working with cattle. Over four thousand (n= 4495) beef and dairy cattle farmers in Scotland were surveyed and the response rate was 54% (2439) and 1341 injuries were reported by 591 participants (24%). Injuries that occurred during animal clipping affected the upper limbs and were associated with working alone, with beef cattle and with younger age. Ear tagging injuries tended to affect the lower limbs (Lindsay et al 2004).

A cross-sectional study of 325 high school students from agricultural colleges in Western Australia investigated agricultural motorcycle use and injury. The students were at greater risk if self taught OR 2.13 (95% CI 0.99-4.76) cf.; if taught by an adult; if operating the motorcycle at a maximum speed 101 kilometres per hour OR 4.53 (95% CI 1.33-15.40); and if wearing a helmet "sometimes" OR 4.10 (95% CI 1.26-13.36) when compared to those who "always" wore a helmet (Lower et al 2003).

In Colorado a cross-sectional study of 262 youth (13-18 years) investigated the relation between sleep patterns and self reported injury in the preceding year. Univariate analysis was conducted to describe the relationships of study variables with injuries. Multivariate modelling was conducted to assess sleep patterns that were associated with injuries, while controlling for other variables. Sleep patterns associated with increased risk of injuries ($p<0.05$) included: oversleeping and having been late to class; falling asleep in afternoon classes; still awake past 3am; sleeping less than an average of 9.25 hours per night on weekends and on school nights and weekends combined; and sleeping less than an average of 8.5 hours on weekends and on school nights and weekends combined. Researchers concluded that sleep patterns were significantly associated with occurrence of injuries amongst these youth (Stallones et al 2006).

In Greece an analysis of recorded unintentional farm injuries from a routine data base (surveillance) revealed distinct patterns of injury amongst migrant workers, older workers and the young. The young were most at risk of non-traffic related injuries. Researchers noted that farm injuries in Greece are often serious and often result in hospitalisation (Alexe et al 2003).

An analysis of a routine data set on injury outcomes from drive line related incidents, in the United States, between 1970 and 2004, focused on injury outcomes for 151 youth (those under 18 years of age). This age group made up 1 in 4 of all documented agricultural driveline incidents. Serious injuries included amputation (50% of cases); spinal cord injuries

and compound bone fractures. The trend in documented cases was declining with no fatalities recorded in 2004. Male youth were the most vulnerable (13 years) and had the highest frequency of incidents, over 50% of cases occurred to youth aged between 12 and 17 years. Most of the incidents occurred in autumn and augers, elevators and conveyor machines were the most frequently identified mechanisms (Beer et al 2007).

On farm falls for youth less than twenty years old in the United States were examined. Researchers found that falls were a significant contributor to farm related injury and that youth appeared to be at considerable risk. The researchers recommended addressing exposure through providing safe play areas for children and continued efforts to prevent extra riders on farm equipment (Hendricks et al 2004).

An analysis of a routine data set for non-fatal injuries, occupational and non-occupational, for youths on farms in the United States explored the association between the use of ATVs and injury. There are 1.1 million youths estimated to live on US farms, 36% of these operated an ATV in 2001. Youths younger than 16 years were more likely to have operated an ATV than a tractor. There were 2,246 non-fatal ATV related injuries occurred to youths younger than 20 years on US farms in 2001. Seventy-four percent (74%) of these injuries occurred to youths' resident on the farm; males accounted for 69% of these injuries and the majority of injuries were to youth 10-15 years. Most ATV injuries resulted from recreational use of ATVs (58%) and many occurred to youths who were not wearing helmets or using ATVs that were larger than the recommended size for their age (Goldcamp et al 2006).

A study of farm related limb amputations in children was conducted through retrospectively reviewing patient records for the period 1978 and 1992. Two hundred and fifty-nine cases of children who had traumatic amputations were identified, of these 11 met the criteria for this study. The criteria included being aged between 0-16 years of age, sustaining a traumatic, farm-related limb amputation (proximal to the tarsal and carpal bones). All of the cases were children who were not operating machinery but were "in the vicinity" of machinery (McClure et al 2005).

Goldcamp et al (2004) conducted an analysis of farm related youth fatalities (n=695) from a routine data set comprising 50 State vital statistics registries in the United States and considered occupational and non-occupational fatalities in the period 1995-2000. The annual average farm fatality rate was 9.3 fatalities per 100 000 youths with males accounting for 80% of the fatalities. The causes of death included machinery (25%); motor vehicle (17%); drowning (16%); suicide (8%); and homicide (6%) and forty-five percent (45%) of work related fatalities occurred in youth less than 16 years of age. Those less than 16 years of age accounted for 71% of non-work related fatalities.

An analysis of US fatal and non-fatal injury records from national and regional surveillance systems between 1992-1998 found 25.8 per deaths per 100 000 workers and 7.5 non-fatal injuries per 100 workers. Fatalities showed some decline in the 1980s, and were steady in the 1990s. Tractors were the leading cause of death mostly due to overturns. Traumatic injuries were a major concern for youth living or working on farms (Hard et al 2002).

Hard et al (2006) analysed data from a census of occupational injury in the United States and focused on 310 work related deaths to youth (<20 years old) in agriculture between 1992 and 2002. In this period there was a gradual downward trend in fatalities. Rates were higher for young workers in agriculture than youth in other sectors by a factor of 3.6. Fifteen year olds had the highest fatality rates, with the crop production sector having a rate six times that of all 15 year old workers.

An analysis of the effectiveness of a state law change in Wisconsin, explored tractor related crashes in the period 1994-2003. Researchers found that the tractor certification course did not cover the major factors contributing to youth tractor crashes on public roads and that 146 tractor crashes in this period involved operators younger than 16 years on highways, a putative age threshold not covered in the legislation. Since the passing of the Wisconsin Act 455, no significant change in the number of youth tractor crashes occurred, nor was there any reduction in the number of crashes where the youth operator was designated at fault (Marlenga et al 2006).

Meiers' (2001) analysed trauma centre referrals between 1989-1998 exploring fatal and non-fatal injury amongst children and youth revealed 45 children under 19 years of age were injured. The mean age was 7.3 years and 14 of the 45 died. The male to female ratio was 2:1 with 69% surviving their injury. The mechanisms of injury were tractors (33%); animals (29%); other machinery (9%); falls (9%), burns (4%) and 84% of the deaths involved tractors or machinery. There was also seasonal variation with June to October (summer through to autumn) being the most prevalent period and the hours of 1pm-6pm were also the most prevalent time period for injury. Nine of the fatalities were being supervised at the time of injury. Injuries included: orthopaedic (56%); neurologic (42%) and thoraco-abdominal (22%). Seven fatalities had solitary head injuries and thirteen percent of all the injuries resulted in a long term disability. The average transport time to a rural hospital was 1.5 hours and from hospital to trauma centre 2.3 hours, with two of the victims dying on route to hospital.

Research in Australia explored fatal farm injury to children in the period 1989-1992 and revealed an average of 29 deaths per year. Males were more commonly injured than females and children aged less than five years represented the majority of injury cases. The most common location for injury included dams and bodies of water, where the cause of death was drowning. Other common mechanisms for injury were tractors and utilities (Mitchell et al 2001).

Mitchell et al (2002) conducted another analysis of an administrative data set recording work-related injury rates in Australia for the periods 1982 to 1984 and 1989 to 1992 paying particular attention to the injury rates for young adults (15-24 years) and older adults (aged 55 years and over). Rates of work related injuries were higher in both age groups for agricultural work when compared with all industries for both the 1982 to 1984 data set and the 1989 to1992 data set. Motor vehicles and firearms were the most common mechanism for young adults (15 to 24 years).

An analysis of fatal injury for youth aged 16 to 19 years in the United States for the period 1982 to 1994 revealed 550 on farm fatalities for youth where 40% of these deaths were occupationally related. The proportions of death attributable to work increased with age. In this period there was a slight decrease in on farm non-occupational deaths and a dramatic increase in occupationally related deaths (12.0 deaths per 100 000 for 1982 to 1985 down to 4.9 deaths/100 000 for 1991 to 1994). The leading causes of death were machinery (54%) and electric current mishaps (20%). On farm fatalities that were non-occupational included drowning (38.9%) and firearms (28.6%). Between 1991 and 1994 drowning and firearms accounted for the same number of on farm deaths as machinery related farm deaths (Myers 2001).

An analysis of non-fatal and fatal injuries in agriculture in British Columbia (BC), Canada in the 1990 to 2000 period revealed 82 fatal injuries from 1990 to 2000 and 1407 hospitalisations 1991/92-1999/2000. No significant overall incidence trends were observed in this period. Machinery related hospitalization rates were lower in BC than in other parts of Canada. Hospitalization rates for non-machinery related injury for young adult BC farmers were high when compared to other regions in Canada (Saar et al 2006).

Sosnowska (2007) conducted an analysis of non-fatal farm related injuries to children in Poland which revealed that 13 to 15 year old males were most at risk of injuries from falls while working unattended or whilst assisting in the work performed by adults; inside and outside and in the summer.

A prevalence survey of 26 000 farm households in the United States explored non-fatal animal related injury for youth. The survey identified 6 438 on-farm animal related injuries to youth in 1998 with 70% of these injuries occurring to youth who were farm residents. Sixty-nine percent (69%) of the injuries were work-related with males accounting for 64% of those injured and with 41% of these males being younger than 10 years. The most common mechanisms of injury were: horse related (37%) and cattle related (31%). The majority of horse related injuries occurred to females and the majority of cattle related injuries to males. Most cattle related injuries were also work related, while most horse related injuries were non-work related. One out of five youth injuries in this study were animal related (Hendricks et al 2001).

Another prevalence survey in the United States of 2000 ‘racial’ minority farms considered non-fatal injury risk and exposures. It is estimated there are 28 600 household youth on ‘racial’ minority farms in the United States. Forty one percent of the youth worked, 28% rode a horse; 23% drove an ATV and 23% operated a tractor. On the Hispanic farms there were 17 999 household youth, 41% of whom worked; 30% rode a horse; 27% drove an ATV and 25% operated a tractor (Hendricks et al 2005).

Reed (2006) conducted a prevalence survey of 593 youth (aged between 14-19 years) who perform work on farms in Kentucky, Iowa and Mississippi and explored injury risk and exposure (Reed 2006). Boys were found to be at higher risk of exposure than girls and were engaged in more risky behaviour. Hearing and respiratory protection was being used only

sparingly and sporadically. The use of respiratory and hearing protection was more prevalent if the individual had physical symptoms and/or if it was recommended by a physician. Sixty percent of youth in this study reported using equipment with damaged or missing safety shields while only 50% of the youths who operated tractors used safety bars and seat belts frequently.

A prevalence survey in Wisconsin explored: musculoskeletal discomfort, injuries and work activities of children and adolescents working in fresh vegetable production. Fifty percent of the adolescents reported lower back pain and 25% reported disabling discomfort. The researchers recommended further research with a larger and more representative sample (Chapman et al 2003).

An observational study in Kentucky (Browning et al 2001) documented the extent of tractor driving amongst children living and working on farms. The researchers found that children and youth commonly operated tractors without ROPS on public roads, and took extra riders, despite knowing this to be hazardous. Farms with annual incomes greater than $10 000 tended to use youth for tractor operation for more days than other farms. Researchers recommended further research.

Another observational study in the United States considered the physical demands of farm work for children and adolescents and found that the magnitude of several work related factors, such as weight and horizontal arm and trunk motions were equal or greater to those associated with high injury risk occupations previously assessed in industrial workplaces (Allread et al 2004).

5.6 Ages 35 -59 years

5.7 Summary of Studies

- In the United States being less than 45 years of age is associated with a higher risk of low back injury, and low back pain (Sprince et al 2007; Park et al 2001). A higher risk of injury is reported amongst 35 to 44 year olds (Carlson 2005) and there is a higher risk of animal related injury (Sprince et al 2003c).
- In Canada researchers' explored machinery related farm injuries in Saskatchewan and found older age to be a predictor of the rate of injury (Hagel 2004).
- In Australia the most at risk in this age group are men (40 to 49 years) in the meat cattle sector; farmers and farm managers; with mechanisms of injury including farm vehicles, mobile farm machinery, transport for work purposes, and working with crops (Franklin et al 2001).
- In New Zealand most compensation claimants for noise related injury are middle aged and older men, with claims from male workers in the agricultural sector disproportionately represented (Thorne 2008).

5.8 The studies:

A cohort study of 6999 Iowa farmers identified a subset of 49 male farmers with low back injury and compared them with 465 uninjured male controls. Researchers concluded that age less than 45 years is a risk factor significantly associated with low back injury. Confounding

was considered for age and education (Sprince et al 2007). A cohort study of 3 765 households across five states in the United States exploring all injury showed variance by age, with men in the 35-44 year age group being at higher risk of injury (Carlson 2005).

In a further cohort study of these 6999 Iowa farmers 116 farmers were identified as having an animal related injury in the last twelve months and were compared to 342 farmer large livestock control farmers who had not been injured in the last year. Multiple logistic regression analysis demonstrated age less than 45 years to be significantly associated with animal related injury (Sprince et al 2003c).

In Canada researchers explored the effect of age on hospitalised machine-related farm injuries among the Saskatchewan farm population in the period 1990-2000. Among the injured cohort older age was a significant predictor of the rate of injury. There was also variance in the type of injury, mechanism of injury and type of machine by age group (Hagel 2004).

An analysis of a routine data set on work related fatalities in farming in Australia between 1989 to 1992 revealed a fatality rate of 20.6 per 100 000 workers per year or 5.3 per 10 000 in agricultural establishments. The most at risk were males aged 40 to 49 years, in the meat cattle sector, farmers and farm managers, using farm vehicles and mobile farm machinery, while being transported for work purposes, under maintenance, working with animals and working with crops, or in a paddock or road/lane. The major mechanisms were vehicle related, such as hit by moving objects and rollovers (Franklin et al 2001).

Thorne (2008) reviewed an administrative data set for the period 1995 to 2006 exploring occupational noise related exposure and hearing loss in New Zealand. The researcher observed that the current data base in New Zealand is unreliable. Accident compensation data revealed a substantial increase in claims annually, from 2823 in July 1995 to June 1996; to 5580 in July 2005 to June 2006 creating a six fold cost increase costing $193.82M. Agriculture, fisheries, trades workers, machine operators, and assemblers accounted for 53% of new claims. Most claimants were middle aged and older males (95%).

The Park et al (2001) prevalence survey of 287 Iowa male farmers from 1992 to 1994 compared them to a general working population and explored self-reported lower back pain over the last twelve months. Thirty one percent of farmers reported daily back pain for a week or more during the past 12 months, compared to 18.5% in the general working population. Middle aged farmers and those with additional non-agricultural employment had the highest risk of back pain (Park 2001).

5.9 All age groups

A cohort study of 1765 family farms in Canada (Ontario) exploring all injury, revealed that injury patterns and risk factors across all age groups were heterogeneous, with falls and machinery risks consistently the top three mechanisms responsible for injury outcomes across all age groups (Bancej 2000).

6.0 Summary of non-fatal injury and fatal injury amongst older age groups:

- In the United States an increased incidence of musculoskeletal conditions was observed amongst older age groups; specifically neck and shoulder problems (Gomez et al 2003). Older workers were also at greatest risk of farm related fatalities (Hard et al 2002). In Canada, males over 60 years have a higher risk of farm related injuries, with the most common mechanisms being tractors and farm machinery (Dimich-Ward 2004). In Canada older age was a significant predictor in hospitalised machine related farm injuries amongst the farm population of Saskatchewan farm population (Hagel 2004).
- In Europe, older women were at greater risk of farm related injury resulting in lower limb fractures (Alexe et al 2003).
- In Australia a greater risk of horse related work injury occurred in males in older age groups (Davies and Franklin 2006). Also those over 55 years have the highest injury rate for agriculture with tractors the most common mechanism of injury (Mitchell et al 2002).
- In New Zealand there appeared to be elevated risks for farm related injuries for older workers (Feyer et al 2001). Another study in New Zealand explored slips, trips and falls in dairy farming and found older age groups to be more at risk (Bentley & Tappin 2004).

6.1 The studies:

A cohort study of 1706 people in New York counties revealed increased risk of musculoskeletal conditions amongst older age groups, specifically increased risk of neck and shoulder problems (Gomez et al 2003). A further cohort study comprising 6999 Iowa farmer identified 79 farmers who had a fall related injury and compared these farmers with 473 farmer controls with no injury over the last 12 months. Researchers noted that aging was a risk factor with a significant association for a fall related injury (Sprince et al 2003b). Hearing impairment and health impairments such as arthritis were also identified as risk factors for fall related injuries (Sprince et al 2003b). A cohort study of 89 sick leave claimants for neck/shoulder/upper extremity problems and 198 claimants for back problems were compared to 816 controls that had made no claim, and found risk factors increased with age for back, neck, shoulder and upper extremity troubles (Hartmann et al 2006).

In Greece an analysis of 4 326 unintentional farm injuries recorded in a routine data set revealed distinct injury patterns for older women, predominantly lower limb fractures related to falls and machinery (Alexe et al 2003).

An analysis of a routine data set recording horse and motorbike injury presentations at one hospital in Australia revealed that horse related injuries occurred predominantly in females while mustering, or riding for leisure. For males, horse related injuries occurred when riding for work and in older age groups (Davies and Franklin 2006).

Dimich-Ward (2004) analysed 726 cases of farm related injury records in a national surveillance data base in Canada for farm related injury. Regardless of how the injury occurred there were a greater number of injured males (665 males to 61 females) and

particularly when farm machinery was involved. Fatal injuries included vehicle roll over (32%) for males and run over (45%) for females. Males over the age of 60 years had a greater number of farm related injuries.

In Canada researchers explored the effect of age on hospitalised machine-related farm injuries among the Saskatchewan farm population in the period 1990-2000. Among the injured cohort older age was a significant predictor of the rate of injury. There was also variance in the type of injury, mechanism of injury and type of machine by age group (Hagel 2004).

In New Zealand, Feyer et al (2001) analysed mortality data for those aged 15 to 84 years and explored the number and rates of work related fatal injury in the period 1985 to 1994. The work-related fatal injury rate in New Zealand was 5.03/100 000 workers per year in the period 1985 to 1994. Elevated rates were observed for older workers, male workers, self employed workers and particular occupational groups, including: agriculture, helicopter pilots, forestry and fishery. Farmers, foresters and fishery workers accounted for 40% of these deaths.

Another study in New Zealand explored slips, trips and falls amongst those engaged in dairy farming and found that older age groups were more at risk and that those in the 50 plus age range are more likely to incur an injury following a fall which requires time off work due to age related physiological factors (Bentley & Tappin 2004).

An analysis of US fatal and non-fatal injury records from national and regional surveillance systems between 1992 to 1998 found 25.8 deaths per 100 000 workers and 7.5 non-fatal injuries per 100 workers. Fatalities showed some decline in the 1980s, and were steady in the 1990s. Tractors were the leading cause of death mostly due to overturns. Older farmers had the highest risk of farm fatalities (Hard et al 2002).

Mitchell et al (2002) conducted an analysis of an administrative data set that records work-related injury rates in Australia for the periods 1982 to 1984 and 1989 to 1992 paying particular attention to the injury rates for young adults (15 to 24 years) and older adults (aged 55 years and over). Rates of work related injuries were higher in both age groups for agricultural work when compared with all industries for both the 1982 to 1984 and the 1989 to 1992 periods. Older adults had the highest injury rate for agriculture and tractor use was the most common mechanism of injury for older adults.

6.2 Summary of non-fatal injury and fatal injury and gender:

In all three regions injury rates are distinctly gendered, with boys, young men, middle aged men and older men at higher risk of non-fatal and fatal injury.

- In the United States, men with a prior history of injury were more at risk (Carlson et al 2000) and men aged between 35 to 44 years had a greater risk (Carlson et al 2006). There was an increased risk for male youth with ATVs (Jones 2005) and they were more at risk of driveline related injury and fatal injury (Beer 2007). Boys engaged in more risk taking behaviour and were at greater risk of injury (Reeds 2006). Male

Amish children had elevated rates of farm injury (Hubler 2002). Males accounted for 80% of all work related fatal injuries in agriculture (Goldcamp et al 2006), while women living on farms were more likely to die from homicide (Liller & Lehtola 2000). Men had elevated rates of lower back pain (Park 2001). Male youth and those aged less than 10 years were at greater risk of injury from horses and cattle (Hendricks et al 2001). For women an increased risk of osteoarthritis was observed for those who worked in farming for 11 to 30 years, with other observed risk factors including excess weight, heredity and previous knee injury (Holmberg et al 2004). Women were also at increased risk of injury if large animals were present, from greater time commitment on the farm, from recurrent or persistent back conditions, from hauling goods, and if they drove a tractor for more than 52 days (Carruth et al 2002). Children were at more risk if maternal age was less than 25 years and if they had two or more siblings (Flower et al 2006). In Canada males were also most at risk (Dimich-Ward 2004); male children had a 2:1 fatal and non-fatal injury rate when compared to females (Meiers 2001) and all children on farms in Canada had an elevated fatal injury rate (Brison et al 2006). A study of routine data exploring agricultural machinery injuries in Ontario in the period 1985-1996 compared the injury rates of males and females and concluded that gender specific injury patterns exist (Locker et al 2002). Fatalities in grain storage bins in the United States involved a significant number of children and were also gendered with 96% of the fatalities occurring to males (Kingman et al 2001).

- In Europe, men had elevated risk of injury from hand transmitted vibration (Palmer et al 2000). Young men also had an elevated risk of injury from falls (Sosnowska et al 2000). They also had elevated fatal and non-fatal injury if they were new to industry and if they were engaged in on-farm forestry (Solomon et al 2007).
- In Australia males had elevated fatality rates, particularly for those aged 40 to 49 working in the meat cattle sector (Franklin et al 2001); elevated rates of non-fatal injury from motorcycles (Davies and Franklin 2006) and riding horses for work (Davies and Franklin 2006). Males in general had greater risk of injury in agriculture (Franklin and Davies 2003).
- In New Zealand, males had elevated fatality rates (Feyer et al 2001) with male agricultural workers having a fatal injury rate of 21.2/100 000 (in the period 1985 to 1994) and the most common mechanisms including machinery and motor vehicles with tractor over turns the most common event (Horsburgh et al 2001). Middle aged men were more likely to present for compensation for noise induced hearing loss (Thorne 2008).

6.3 The studies

Carlson et al (2005) undertook a cohort study of 3 765 households across five states in the United States and demonstrated that men with prior injury history were at greater risk of injury and men in the 35 to 44 age group were a high risk group. Merchant et al (2002) cohort study in South Eastern Iowa explored all injury, mechanisms of injury and socio-demographic factors and revealed men had higher injury rates, were more likely to be obese and overweight, had higher rates of hearing loss and were less likely than women to consult a

medical practitioner about health problems. Women, in contrast, had poorer emotional health and higher rates of depressive symptoms.

In another cohort study of 21 360 children in Iowa and North Carolina revealed excess agricultural machinery mortality in Iowa was found and increased risk for children was associated with maternal age less than 25 years and if there were two or more siblings in the family (Flower et al 2006).

A significant risk of joint problems amongst older women was identified in a cohort study of 1706 people in New York counties (Gomez 2003). Joint problems were also more common amongst owner/operators, who experienced an increased risk of neck/shoulder and lower back trouble, whereas for workers there was an increased risk of neck/shoulder trouble. Undertaking tractor work was associated with problems in all five joint areas, and milking was associated with knee trouble. The findings indicated that personal risk factors and the intensity and nature of the farm work contribute to joint problems. Researchers concluded that ergonomic improvements to tractors and milking facilities should be a high priority (Gomez 2003).

A cohort study of 778 participants with x-ray verified osteoarthritis in the femorotibial joint, across a range of occupations was compared with 695 controls. Analysis showed that farm work was not related to an increased risk for men. However, women who had worked for 11-30 years in farming tended to have an increased risk. Other identified strong risk factors included: excess weight, heredity and previous knee injury (Holmberg et al (2004).

The Carlson (2005) cohort study of 3 765 households across five states in the United States exploring all injury showed variance by age, with men in the 35 to 44 year age group being at higher risk of injury.

A cross sectional study of 1096 farm women in Texas and Louisiana found factors predictive of increased risk of injury included: presence of large animals, greater time commitment, recurrent or persistent back conditions or weakness in last 12 months, hauling goods to market, and driving a tractor for more than 52 days a year (Carruth et al 2002).

In another cross-sectional study of 652 youths participating in agricultural training programmes throughout the state of Arkansas, researchers explored ATV behaviours, exposures and injuries for farm youth and compared these with the behaviours of non-farm youth. Sixty percent of the students had operated ATVs within the past month. Farm youth were more likely to be white, male, to own a 3 wheel ATV and to ride more often with a single rider. The risk factors included frequency of use and number of people riding on the ATV (Jones 2005).

Another cross-sectional study of 22 194 men and women aged 16 to 64 years in England, Scotland and Wales investigated hand transmitted vibration by occupation and industry. Industries where high vibration exposures occurred were in construction, motor repair, manufacture of basic metals and agriculture. Men across all occupations and industry were identified as most at risk (Palmer et al 2000).

An analysis of a routine data set (injury surveillance) recording injury outcomes from drive line related incidents, in the United States, between 1970 to 2004, focused on injury outcomes for 151 youth (those under 18 years of age). This age group made up 1 in 4 of all documented agricultural driveline incidents. Serious injuries included amputation (50% of cases); spinal cord injuries and compound bone fractures. The trend in documented cases was declining with no fatalities recorded in 2004. Male youth were the most vulnerable (13 years) and had the highest frequency of incidents, with over 50% of cases occurring to youth aged between 12 and 17 years. Most incidents occurred in autumn with augers, elevators and conveyor machines the most frequently identified mechanisms (Beer et al 2007).

Kingman et al (2001) reviewed the Purdue University database to identify fatal entrapments in on-farm grain storage bins in the period 1966-1998. The fatalities were mainly in association with corn production, with the study also identifying fatalities in Canada – in Ontario. There were many more close calls or near misses documented. In those cases where the age of the victim was known 24% of the victims were aged between 3 and 15 years of age. Those younger than 16 suffocated primarily in June, while older victims suffocated in November, December, January, February and March. The high number of children dying in storage bins is cause of concern. Unloading grain was a significant high risk activity. Where gender was identified, males accounted for 96% of the fatalities.

Beer et al (2007b) also analysed a further routine data set recording injury outcomes from drive line related incidents in the United States between 1970 and 2000 for youth under the age of eighteen years. The following similar patterns were observed: drive line related injury declined in the 1990s and into the 2000s and eleven to fifteen year olds had the highest frequency of cases and incidences happened most commonly in autumn and involved augers, elevators and conveyors as the most common mechanism of injury.

An analysis of a routine data set with records of horse and motorbike injury presentations at one hospital in Australia revealed that horse related injuries occurred predominantly in females while mustering, or riding for leisure. For males, horse related injuries occurred when riding for work and in older age groups (Davies and Franklin 2006). Motorcycle injuries occurred predominantly with males, on two wheel drive bikes while riding for leisure. When 4wd quad bikes were involved in injury the individual was more likely to be admitted to hospital (Davies and Franklin 2006).

Dimich-Ward (2004) analysed 726 cases of farm related injury recorded in a national surveillance data base in Canada for farm related injury. Regardless of how the injury occurred, there were a greater number of males injured (665 males to 61 females), and particularly when farm machinery was involved. Fatal injuries included roll over for males (32%) and run over (45%) for females. More males over the age of 60 years had farm related injuries.

Locker et al (2002) explored agricultural machinery injuries in Ontario in the period 1985 to 1996 and compared the injury rates of males and females. The researchers found statistically significant differences in the distribution of injuries among males and among females by age

group, agricultural production season and mechanism of injury. Exposure to machinery differed between genders and there were work assignment differences. Researchers recommended further research into the gendered patterns of injury observed in this study.

Feyer et al (2001) analysed mortality data for those aged 15 to 84 years in New Zealand to explore the number and rates of work related fatal injury in the period 1985 to 1994. The work-related fatal injury rate in New Zealand was 5.03/100 000 workers per year in the period 1985 to 1994. Elevated rates were observed for older workers, male workers, self employed workers and particular occupational groups, including: agriculture, helicopter pilots, forestry and fishery. Farmers, foresters and fishery workers accounted for 40% of the deaths.

An analysis of a routine data set of work related fatalities in farming in Australia between 1989 to 1992 revealed a fatality rate of 20.6 per 100 000 workers per year with 5.3 per 10 000 were on farms. The most at risk were males aged 40 to 49 years, working in the meat cattle sector, farmers and farm managers, those using farm vehicles and mobile farm machinery, while in transport for work purposes, vehicle maintenance, working with animals and working with crops, in a paddock or road/lane. The major mechanisms were vehicle related in particular rollovers and being hit by moving objects (Franklin et al 2001).

An analysis of a routine data set for non-fatal injuries, occupational and non-occupational, for youths on farms in the United States explored the association between the use of ATVs and injury. There are 1.1 million youths who live on US farms, 36% of these operated an ATV in 2001. Youths younger than 16 years were more likely to have operated an ATV than a tractor. Approximately 2,246 non-fatal ATV related injuries occurring to youths younger than 20 years on US farms in 2001 with 74% of these injuries occurring to youths' resident on the farm; males accounting for sixty nine percent of these injuries and the majority of injuries occurring amongst youth aged 10-15 years. Most ATV injuries resulted from recreational use of ATVs (58%) with many occurring to youths who were not wearing helmets or using ATVs that were larger than the recommended size for their age (Goldcamp et al 2006).

Goldcamp et al (2004) analysis of farm related youth fatalities (n=695) from routine data from 50 State vital statistics registries in the United States considered occupational and non-occupational fatalities in the period 1995-2000. The annual average farm fatality rate was 9.3 fatalities per 100 000 youths. Males accounted for 80% of the fatalities. Causes of death included machinery (25%); motor vehicle (17%); drowning (16%); suicide (8%); and homicide (6%). Forty five percent of work related fatalities were to youth less than 16 years of age and those less than 16 years of age also accounted for 71% of non-work related fatalities.

Hubler (2002) study considered Amish children presenting to hospital over a five month period. There were 89 injuries and amongst these 5 fatalities. Male children sustained 64 injuries and female children sustained 25 injuries. Falls were the most common mechanism of injury, followed by incidents involving livestock. Both types of incident most commonly resulted in orthopaedic surgery.

An analysis of fatal injury data for agricultural workers in New Zealand (aged 15 to 84 years), in the period 1985 to 1994, revealed an injury rate of 21.2/100 000 for male agricultural workers. Injury deaths in the agricultural sector accounted for nearly a quarter of all work-related deaths in New Zealand. Those at higher risk included, older women aged from 65 to 84 years. The most common mechanisms included machinery and motor vehicles, and overturns (rollovers) were the most common event (Horsburgh et al 2001).

An analysis of fatal injury data for farmer and farm workers in Florida, in the period 1989 to 1998, revealed adult males were more likely to die on farms than adult females, although females were more likely to die as a result of homicide. In this period there were 231 deaths, 20 deaths were children and 211 deaths were adults with the leading cause of death being machinery for both children and adults (Liller & Lehtola, 2000).

An analysis of trauma centre referrals between 1989 to 1998 explored fatal and non-fatal injury amongst children and youth and revealed 49 children were under 19 years of age were injured. The mean age was 7.3 years, 14 of the 45 died and the male to female ratio was 2:1. Sixty-nine percent survived their injury. The mechanisms of injury were tractors (33%); animals (29%); other machinery (9%); falls (9%), burns (4%). Twelve deaths involved tractors or machinery (84%). There was seasonal variation with June to October (summer to autumn) being the most prevalent period. The hours of 1pm to 6pm were also the most prevalent time period for injury. Nine of the fatalities were supervised at the time of injury and the injuries included: orthopaedic (56%); neurologic (42%); thoracoabdominal (22%) with 13% of the injuries resulting in long term disability and seven of the fatalities involving solitary head injuries. Percentages added up to more than 100% as some presented with multiple injuries. The average transport time to a rural hospital was 1.5 hours, from hospital to trauma centre 2.3 hours and two of the victims died while being transported to hospital (Meiers 2001).

In Australia an analysis of routine fatal injury data explored fatal injury amongst children in the period 1989 to 1992 and revealed an average of 29 deaths per year. Males were more commonly injured than females and children aged less than five years represented the majority of injury cases. The most common location for injury included dams and bodies of water and where the cause of death was from drowning. Other common mechanisms were tractors and utilities (Mitchell et al 2001)

Sosnowska (2007) analysis of non-fatal farm related injuries to youth in Poland revealed that 13 to 15 year old males were at the most risk of injury from such events as falling while working unattended or whilst assisting in the work performed by adults; either indoors or outdoors in the summer.

A review of an administrative data set for the period 1995 to 2006 in New Zealand explored occupational noise related exposure and hearing loss. Accident compensation data revealed a substantial increase in claims for these disorders annually, with 2823 in July 1995 to June 1996; increasing to 5580 in July 2005 to June 2006 amounting to a six fold cost increase over this decade ($193.82M). Agriculture, fisheries, trades workers, machine operators, and

assemblers accounted for 53% of new claims. Ninety five percent of the claimants were middle aged and older males (Thorne 2008).

Brison et al (2006) reviewed fatal injuries for children in Canada for the period 1990 to 2001. Fatal agricultural injury was substantially higher than that of all-cause, unintentional injury among Canadian children aged 1 to 6 years (14.9 v 8.7 per 100 000 person/years respectively). There was an elevated fatal injury amongst boys with 73% of the injuries occurring at the worksite and resulting most commonly from one of three mechanisms; 1) run over by machinery as a bystander (29%); 2) extra rider fell from machine (22%) and/ or 3) asphyxia due to drowning (23%). Of all children, preschool children were at the greatest risk of fatal injury.

In Australia, an analysis of 384 farm related injury cases in New South Wales revealed a rate of 34 injuries per 100 farms. In the majority of cases the victims were men who were employed and resident on the farm and engaged in meat cattle, cereal and poultry production the common mechanisms of injury were horses, motorcycles, other animals and other objects (Franklin and Davies 2003).

Hendricks et al (2001) surveyed 26 000 farm households in the United States and explored non-fatal animal related injury for youth. This survey identified 6 438 on-farm animal related injuries to youth in 1998 with 70% of these injuries occurring to youth who were farm residents. Sixty-nine percent of the injuries were work-related and males accounted for 64% of those injured with 41% of these males being younger than 10 years. The most common mechanisms of injury were: horse related (37%) followed by cattle related (31%). The majority of horse related injuries occurred to females and the majority of cattle related injuries occurred to males. Most cattle related injuries were also work related, while most horse related injuries were non-work related. In summary one out of five youth injuries on US farms at this time were animal related.

In the USA Park et al (2001) explored the prevalence of self-reported lower back pain over the last twelve months. The researchers surveyed 287 Iowa male farmers in the period 1992 to 1994 and compared these farmers to a general working population. Thirty one percent of the farmers reported daily back pain for a week or more during the past 12 months, compared to 18.5% in the general working population. Middle aged farmers and those with additional non-agricultural employment had the highest risk of back pain (Park 2001).

Another prevalence survey explored injury risk and exposure amongst 593 young people aged between 14 to 19 years who perform work on farms in Kentucky, Iowa and Mississippi. Boys were found to be at higher risk of injury than girls and were more likely to be engaged in risky behaviour. Hearing and respiratory protection was used sparingly and only sporadically with the use of respiratory and hearing protection more prevalent if the individual had physical symptoms or if it was recommended by a physician. Sixty percent of the youth reported using equipment with damaged or missing safety shields and 50% operated tractors using safety bars and seat belts (Reed 2006).

Solomon et al (2007) recorded life time histories of work in agriculture and occupational injury for men born in the period 1933 to 1977 in Britain. The incidence of injury reported by self-employed farmers in this study, were higher than those reported to statutory bodies. The highest rates of injury were from handling, lifting, and carrying (4.9/1000 person-years); from falls from heights (4.6/1000 person-years); and injury by animals (3.4/1000person-years). The risk of injury for men was elevated when they had only recently entered agriculture and for those who also carried out forestry (Solomon et al 2007).

6.3 Ethnicity

While ethnicity and its relation to work status, socio economic status, and health outcomes is a key feature of the agricultural workforces of all three regions, the research record does not often address these issues directly nor does it explore how the relation between ethnicity and social position may determine injury risk and outcomes amongst all workers in agriculture. Only three studies addressed this explicitly (albeit in a very limited way) and all three were conducted in the United States.

- In the USA, young farm workers in Arkansas are most likely to be white, male and own a 3 wheel ATV. Frequency of use of the ATV and number of people riding on the ATV are both risk factors (Jones 2005). A survey of "Racial" minority farms included approximately 28 000 households with young people resident, of which 41% worked and were exposed to the following risks: horses, ATV's, tractors. No injury outcomes considered by these researchers (Hendricks et al 2005). A survey of farm operators explored the factors associated with farm work related injury and found these included: white ethnicity, increased annual hours worked on farm; low levels of administrative work; increased time working with animals. Researchers concluded multiple injuries to individuals were suggestive of an interaction between personal and environmental risk factors (McCurdy et al 2004).

6.4 The studies

A cross-sectional study of 652 youths in agricultural training programmes throughout the state of Arkansas explored ATV behaviours, exposures and injuries for farm youth and compared these with non-farm youth. Sixty percent of the students had operated ATVs within the past month. Farm youth were more likely to be white, male, to own a 3 wheel ATV and to ride more often with a single rider. Risk factors included frequency of use and number of people on the ATV (Jones 2005).

A prevalence survey in the United States of 2000 'racial' minority farms considered non-fatal injury risk and exposures. It is estimated there are 28 600 household youth on 'racial' minority farms in the United States. Forty-one percent of the youth worked, 28% rode a horse; 23% drove an ATV and 23% operated a tractor. On Hispanic farms there are an estimated 17 999 household youth, 41% of whom worked; 30% rode a horse; 27% drove an ATV and 25% operated a tractor (Hendricks et al 2005).

A prevalence survey of 1947 farm operators in the United States explored self-reported non-fatal injury over the preceding year. One hundred and thirty five farm operators reported work related injuries in the preceding year with the cumulative incidence rate for any farm

work related injury being 6.9%, or a mean of 8.2 farm work related injuries per 100 farmers in the preceding year. Multiple injuries in the same individual occurred more frequently than chance. Sprains and strains were the most common (29.4%) conditions of the back with overexertion the most common external cause (24.5%); machinery related injury account for fourteen percent (14.3%); falls related injury account for thirteen percent (13%); and animal related injury account for twelve percent (12.4%). The factors associated with farm work related injury included: white ethnicity, increased annual hours worked on farm; low levels of administrative work; increased time working with animals. The researchers concluded that multiple injuries to individuals were suggestive of interaction between personal and environmental risk factors (McCurdy et al 2004).

6.5 Health risk behaviours: including obesity and overweight, fitness, smoking, risk taking.

6.6 Summary of Studies

- Three studies which addressed health risk behaviours were conducted in the United States, with one cohort study, one cross sectional survey and one prevalence study. An association between increased body mass, smoking and former pain was found amongst sick leave claimants seeking compensation for neck, shoulder and upper extremity problems and back trouble (Hartmann 2006). High risk behaviour amongst South Texan youth was more commonly associated with non-farm work related injury, rather than work-related injury (Ascota et al 2007). Boys, particularly those aged between 14 and 19 years engaged in more risky behaviour than girls in Kentucky, Iowa and Mississippi (Reed 2006).

6.7 The studies:

A cohort study of 89 sick leave claimants for neck/shoulder/upper extremity problems and 198 for back trouble were compared with 816 controls that did not make claims in this period. Multivariate analysis showed that risk factors increased with a body mass index greater than 27.0; with smoking; and with a history of former pain associated with sick leave claims for neck, shoulder, upper extremity and back troubles (Hartmann 2006).

A cross sectional study of 4 914 high school students (9^{th} grade) in a South Texas rural district considered health risk behaviours and work and non-work related injury. An aggregate risk score (ARS) was developed based on health risk behaviours. Mean ARS scores were significantly higher ($p<0.05$) for both male and female adolescents who had reported a work related injury compared to non-working adolescents; and for males who had done migrant farm work when compared with other males who had not done so. A statistically significant association between ARS and non-farm work related injury was found, but not between ARS and farm work related injury. Farm workers with high ARS scores were more likely to report non-farm work related injuries (Ascota et al 2007).

A prevalence survey of 593 youth (aged between 14 to 19 years) who perform work on farms in Kentucky, Iowa and Mississippi explored injury risk and exposure with boys found to be at higher risk of exposure than girls. Boys were engaged in more risky behaviour than girls. Hearing and respiratory protection was used sparingly and only sporadically. The use of

respiratory and hearing protection was more prevalent if the individual had physical symptoms or if it was recommended by a physician. Sixty percent of the youth reported using equipment with damaged or missing safety shields. Only 50% of the youths operated tractors and frequently used safety bars and seat belts (Reed 2006).

6.8 Alertness/Fatigue

The relation between risk of injury and alertness and or fatigue was explored in two studies, both in the United States.

6.9 Summary of Studies:

- Two cross sectional studies both in the United States investigated sleep patterns and self reported injury. The first found that sleep patterns were associated with an increased risk of injuries amongst youth (13 to18 years) (Stallones et al 2006). The second study found hours of sleep were not related to injury incidence. However, those participants who were using sleep medication and those with a history of sleep apnoea had an increased risk of injury (Spengler et al 2004).

7.0 The studies:

A cross-sectional study of 262 youth (13 to 18 years) in Colorado investigated the relation between sleep patterns and self reported injury in the preceding year (Stallones et al 2006). Multivariate modelling was used to assess sleep patterns that were associated with injuries, while controlling for other variables. Sleep patterns were associated with increased risk of injuries ($p<0.05$) and included: oversleeping and having been late to class; falling asleep in afternoon classes; still awake past 3am; sleeping less than an average of 9.25 hours per night on weekends and on school nights and weekends combined; and sleeping less than an average of 8.5 hours on weekends and on school nights and weekends combined. The researchers concluded sleep patterns were significantly associated with occurrence of injuries amongst these youth.

A cross sectional survey of 1004 part time male farmers in Kentucky explored self reported sleep habits and injury occurrence requiring medical attention in the previous 12 months. Twelve percent reported an injury requiring medical attention in the last year. Farmers reported sleeping an average of 7.6 hours per day and 6.7% of the sample reported symptoms of sleep apnoea. However, results demonstrated that hours of sleep were not related to injury incidence. However, participants using sleep medication and the presence of sleep apnoea were related to injury incidence amongst these farmers (Spengler et al 2004).

A nested case control study undertaken in the United States examined sleep propensity measured using the Epworth Sleepiness Scale. High sleepiness scores were not associated with an increased risk of farm work-related injury (Sprince et al 2003).

7.1 Injury risk and exposure and education level

7.2 Summary of Studies:

- Three cohort studies of Iowa farmers found significant associations between farm-work related injury and education beyond high school (Sprince et al 2003); education

beyond high school was identified as one of four risk factors (confounding for age and education – the younger age group was more educated than the older age groups) (Sprince et al 2007). A significant association was observed between education beyond high school and risk of animal injury.

7.3 The Studies:

The previously described cohort study of 6 999 farmers in Iowa (Sprince et al 2003) identified 431 farmers with a history of injuries in the previous 12 months and 473 controls with no such injury. Significant associations between farm-work related injury and education beyond high school were found (Sprince et al 2003).

A subset of 49 male farmers from the Iowa cohort study (Sprince et al 2007), with low back injury were compared with 465 uninjured male farmer controls. Level of tertiary education was identified as one of four risk factors. Confounding for age and education was conducted (the younger age group were more educated than the older age groups). The other three risk factors identified included: age less than 45 years, medically diagnosed asthma and hearing difficulties (Sprince et al 2007).

Sprince et al (2003c) third cohort study of 6999 Iowa farmers identified another subset of 116 farmers with large livestock who had animal related injury requiring medical intervention in the last 12 months and compared with 342 farmer controls, with large livestock, who had not been injured in the last 12 months. Multiple regression analysis showed a significant association between animal related injury and education beyond high school (increased education).

7.4 The association of injury risk and exposure and outcome with diagnosed medical conditions

7.5 Summary of Studies

- Four studies in the USA, including three cohort and one cross sectional study addressed the association of injury risk and exposure and outcome with diagnosed medical conditions. Researchers found that physician diagnosed asthma was a significant risk factor in low back injury (Sprince et al 2007). Significant associations were also shown for animal related injury and doctor diagnosed arthritis or rheumatism (Sprince et al 2003c). There was also an apparent increased risk of developing radiologically verified osteoarthritis in the tibio-femoral joint for women who had worked in agriculture for 11 to 30 years with other identified risk factors being excess weight, hereditary and previous knee injury (Holmberg et al 2004). Increased risk was also observed for people who had recurrent and/ or persistent back conditions or weakness in the last twelve months (Carruth et al 2002).

7.6 The studies

Sprince et al (2007) Iowa cohort study identified a subset of 49 male farmers with low back injury who were compared with 465 uninjured male farmer controls. Medically diagnosed asthma was a risk factor significantly associated with low back injury even when taking age and education into consideration.

A further cohort study (Sprince et al 2003c) identified 116 farmers with large livestock who had animal related injury requiring the farmer to have medical intervention and compared this to 342 farmer controls with large livestock who had not been injured in the last year. A significant association was found between animal related injury and doctor diagnosed arthritis or rheumatism.

A cohort study of 778 rural participants with x-ray verified osteoarthritis in the tibio-femoral (knee) joint across a range of occupations was compared with 695 controls. Multiple regression analysis showed that farm work was not related to an increased risk for men. However, women who had worked for 11 to 30 years in farming tended to have an increased risk. Other identified strong risk factors were: excess weight, heredity and previous knee injury. Smoking showed a negative relationship to knee osteoarthritis (Holmberg et al (2004).

A cross sectional study of 1096 farm women in Texas and Louisianna found factors predictive of increased risk of injury included recurrent or persistent back conditions or weakness in the last 12 months (Carruth et al 2002).

7.7 Prescription drug use and injury risk, exposure and outcomes

The search found two case control studies, both in North America which investigated the relationship between prescription drug use and injury risk, exposure and outcomes in agriculture.

7.8 Summary of Studies

- A case control study in Canada reported increased risk of injury for farmers who had recently stopped taking pain killers and anti-inflammatories (Voaklander 2006).
- A case control study in the United States found significant associations between farm-work related injury and regular medication use (Sprince 2003).

7.9 The Studies

A case control study by Voaklander et al (2006) in Alberta amongst older male farmers revealed that distraction from pain or co-morbidity might play an important role in the aetiology of injuries. Farmers who stopped taking narcotic pain killers (OR 9.37, 95% CI 4.95 – 17.72) and non-steroidal anti-inflammatories (OR 2.40, 95% CI 1.43-4.03) in the 30 days prior to injury were at risk of injury, after controlling for co-morbidities. This study considered all injuries that resulted in hospital or emergency care. Further examination of possible effect modification of physical functioning and medication use was recommended by the authors to examine other known risk factors of injury in the elderly.

Sprince (2003) found significant associations between farm-work related injury and regular medication use in their case control study which identified and compared 431 farmers with 473 controls with no injury in the previous 12 months. Multivariate analysis reported an increased risk of farm work related injuries in those taking regular medication.

8.0 Hearing Impairment

8.1 Summary of studies which addressed hearing impairment

- Four studies were found including two cohort studies and one convenience sample in the USA and one cross sectional survey in New Zealand. Significant associations were found between hearing impairment and fall related injuries (Sprince et al 2003 and Sprince 2003b) and between machinery related injuries and wearing a hearing aid (Sprince 2002). Self reported hearing loss in the left ear predicted hearing handicap (Carruth et al 2007). The majority of farmers in the New Zealand study had a moderate risk of hearing loss with a minority having a high risk of significant hearing loss (McBride 2003).

8.2 The Studies

Sprince et al 2003 a & b cohort study demonstrated associations between farm work related injury and the wearing of a hearing aid and found significant associations between hearing impairment and fall related injuries. Sprince et al (2003b) cohort study of 6999 Iowa farmers, identified a subset of 79 farmers with fall related injury and 473 controls with no injury over the last twelve months. The researchers found significant associations between hearing impairment and fall related injuries.

Sprince et al (2007) compared 49 male farmers with low back injury and 465 injured male farmer controls and revealed hearing difficulties to be one of four risk factors significantly associated with low back injury. Animal related injury was found to be significantly associated with the use of a hearing aid (Sprince 2000c) as were machinery related injuries significantly associated with wearing a hearing aid (Srpince et al 2002).

Noise induced hearing loss was examined in Texas and Louisiana amongst a convenience sample of 56 farmers and family members recruited at an agricultural event. The analysis showed significant associations between high frequency hearing loss in the left ear and the attitude that wearing hearing protection prevents others from getting one's attention. Interestingly, self reported hearing loss in the left ear significantly predicted hearing handicap (Carruth et al 2007).

McBride (2003) undertook a cross sectional study of 586 farm workers in New Zealand and explored the relation between risk and exposure to noise and hearing loss amongst farmers. Median noise exposures on a subsample of farms (60) lay between 84.8 to 86.8 dB(A) with maximum exposures in the order of 94 dB(A). Hearing losses were consistent with this level of exposure. Important risk factors included: age, driving tractors without cabs and working with metal. Reported compliance with hearing protection was greater than that observed on site and the majority of farmers had moderate risk of hearing loss. A minority of farmers had a risk of significant hearing loss.

8.3 Alcohol consumption and substance use

8.4 Summary of Studies

- Three studies, all in the United States, including one cohort study, one nested case control and one cross sectional survey addressed alcohol consumption and or substance abuse. Significant associations with a high CAGE score (a screening tool for alcoholism) indicated a relationship between problem drinking and injury (Sprince et al 2002, Sprince 2003). Migrant students reporting frequent substance use were more likely to have been injured at work on the farm (Cooper 2005).

8.5 The studies

Sprince et al (2002) cohort study showed a significant association with a high CAGE score indicating problem drinking and machinery related injuries requiring medical assistance.

Sprince et al (2003) nested case control study showed significant association with a high CAGE score indicating problem drinking and farm related injuries in the last 12 months. Having two or more drinks a day or drinking alcohol currently were not associated with a significant increase in risk of injury in the last 12 months.

A cross sectional study of 7302 middle and 3565 high school students, of whom 5% were migrant students' considered work related injury and substance use. Migrant students were more likely to report frequent substance use, more likely to work for pay on weekday mornings before school and more likely to have been injured at work on the farm (Cooper 2005).

8.6 Injury and Production type

Relationships between the type of production practice and injury were explored in three studies in the United States and three studies in Australia.

8.7 Summary of Studies

- In the USA the risk of neck, shoulder and upper extremity problems was found to be associated with pig, mushroom and dairy/pig farming (Hartmann 2006). High rates of low back pain were also observed amongst soybean and corn growers in Kansas (Rosecrance & Merleno 2006). There was a high risk of injury using grain augers, with the highest exposure occurring when using conventional grain augers and gravity flow grain wagons (Wilkinson & Field 2005).
- In Australia, higher injury rates were noted in the sheep sector and during livestock management and handling (Mather and Lower 2001) and amongst those farming meat cattle, cereal and poultry (Franklin & Davies 2003). High rates of self inoculation injury were found amongst sheep farmers (Windsor et al 2005).

8.8 The Studies

In the USA, Hartmann et al (2006) conducted a cohort study focussing on the risk of neck, shoulder and upper extremity conditions associated with pig, mushroom and diary/pig farming. The researchers found an increased risk of neck, shoulder and upper extremity problems was associated with pig, mushroom and dairy/pig farming.

A cross sectional study of 506 farms in Australia, covering all production types, explored self reported injury in the preceding two years. Researchers found higher injury rates were reported in the sheep sector, with vehicles, hand tools and handling livestock to be the main mechanisms of injury (Mather and Lower 2001).

An analysis of 384 farm related injury cases in New South Wales, Australia revealed a rate of 34 injuries per 100 farms. In the majority of cases the victims were men, who were employed and resident on the farm and engaged in meat cattle, cereal and poultry production. Common mechanisms of injury were horses, motorcycles, other animals and other objects (Franklin and Davies 2003).

In a study of injuries resulting from self inoculation in Australia (recorded in an administrative data set), researchers investigated the rates of self-inoculation amongst 50 primary producers vaccinating sheep with Gudair vaccine for control of ovine paratuberculosis. The overall rate of self inoculation was 1 in 7406 vaccinations, 21 incidents of exposure with 5 superficial skin contact and 16 penetration incidences without vaccine. Six of the cases needed medical intervention and three required extensive surgery (Windsor et al 2005). Risk factors for self inoculation were not considered by the researchers.

A prevalence survey of 499 active farmers in Kansas (Rosecrance & Merleno 2006) explored self-reported back pain over the previous 12 months and considered both exposure and risks. Lower back pain was the most prevalent (37.5%); followed by shoulder (25.9%); knees (23.6%) and neck (22.4%) disorders. Close to 60% of participants experienced back pain in at least one of the nine body areas in the previous year. Nearly a quarter of the participants saw a medical practitioner about their back pain; and one in five had to modify their work practices due to low back symptoms in the last year. Kansas farmers had higher rates of low back pain compared to the general working population and other farmers in other regions. Researchers observed that these higher rates may be linked to the type of agricultural production in Kansas which is predominantly soybean and corn growing (Rosecrance & Merleno 2006).

In an on-site observational survey of farms in the US, researchers observed exposure to conventional grain augers while unloading from trucks and wagons; extended dump hopper augers, and swing away augers. Operators had higher exposure time to operating PTO components when the driveline was located on the right side of the grain auger, as one stands facing the hopper end of the auger; than they did on the left side of the auger when using conventional grain augers and grain trucks. This added exposure was due to the position of the driver's door of the truck, the natural path of the driver from the operator's seat to the rear of the truck and the movement of the truck body into the workspace when tilted. The operators had the highest exposure when using conventional grain augers and gravity flow grain wagons and operators had no recorded exposure time when operating swing-away hopper augers. The researchers recommended reconfiguring the way augers are incorporated into grain handling operations (Wilkinson & Field 2005).

8.9 Agricultural workers

Very few studies specifically focussed on agricultural workers (as opposed to owner operators). The search found two studies, one a cross sectional survey and the other an analysis of routine data. Both of these studies focussed on migrant workers, agricultural workers that are known to have disproportionately high injury rates.

9.0 Summary of studies

- In the United States a cross sectional study found frequent substance use by migrant youths working on farms was more likely to lead to injury at work (Cooper 2005)
- In Greece, migrant workers were more at risk of injuries from cutting, piercing from agricultural instruments and or equipment, falls from high levels, and insect and snake bites (Alexe et al 2003).

9.1 The Studies

In the USA a cross sectional study of 7302 middle and 3565 high school students of whom 5% were migrant students' considered work related injury and substance use. Migrant students were more likely to report frequent substance use, more likely to work for pay on weekday mornings before school and more likely to have been injured at work (Cooper 2005).

An analysis of unintentional farm injuries recorded in a routine data base (surveillance) in Greece revealed distinct patterns of injury, including migrant workers being more at risk of injuries from cutting, piercing from instruments, falls from high levels and insect and snake bites (Alexe et al 2003). No confounders were considered.

9.2 Attitudes and safety behaviours

The search found two studies, one study which considered hearing loss and the wearing of hearing protection and one study that considered the use of safety equipment and factors shaping an individual's willingness to use respiratory and hearing protection.

9.3 Summary of studies

- In the United States there were significant associations between high frequency hearing loss in the left ear an attitude that wearing hearing protection prevents others from getting one's attention (Carruth et al 2007). A study of farm youth in Kentucky, Iowa and Mississippi found the use of respiratory and hearing protection was more likely if the individual had physical symptoms and if it was recommended by a physician. 60% of youth reported using damaged or faulty safety equipment, and only 50% of those operating tractors frequently used safety bars/seat belts (Reed 2006).

9.4 The Studies

A convenience sample of 56 farmers and family members recruited from a community based agricultural event in Texas and Louisiana examined noise induced hearing loss. Multiple regression analysis showed significant associations between high frequency hearing loss in the left ear and the attitude that wearing hearing protection prevents others from getting one's attention (Carruth et al 2007).

Reed (2006) prevalence survey explored the attitudes (and behaviours of) young people (aged between 14 to 19 years) who perform work on farms in Kentucky, Iowa and Mississippi and found boys to be at higher risk of injury than girls and also engaged in more risky behaviours. They used hearing and respiratory protection sparingly and sporadically. The use of respiratory and hearing protection was more prevalent if the individual had physical symptoms or if it was recommended by a physician. Sixty percent of the youth reported using equipment with damaged or missing safety shields. Only 50% of the youths operated tractors and when they did frequently used safety bars and seat belts (Reed 2006).

9.5 Time spent in agricultural work (actual working hours and employment history)

Researchers had explored both working time and employment history and its relation to injury with three studies being conducted in the United States in this period.

9.6 Summary of studies

- In the United States, one cohort study which showed a significant association between machinery related injury and fewer years of farm experience and a significant association between greater hours spent on farm work and machine related injury (Sprince et al 2002). A nest case control study showed significant associations between farm work related injury and weekly farming hours if > than 50 hours per week (Sprince et al 2003). And a prevalence survey which found factors associated with farm work related injury included: increased annual hours worked on farm; low levels of administrative work; increased time working with animals (McCurdy et al 2004).

9.7 The Studies

Sprince et al (2002) cohort study of 6 999 Iowa farmers identified 205 farmers who had machinery-related injuries requiring medical assistance in the last twelve months and compared with 473 farmer controls who had no injury over the last year. Multiple logistic regression analysis showed a significant association between machinery related injury and fewer years of farming experience. The same cohort study showed a significant association between greater hours spent on farm work and machinery related injury (Sprince et al 2002).

In another nest case control study of 6999 farmers in Iowa (431 identified as having injury in the previous 12 months and 473 controls with no injury in previous 12 months) significant associations between farm-work related injury and weekly farming hours (>=50 hours/week) were found (Sprince et al 2003).

A prevalence survey of 1947 farm operators in the United States explored self-reported non-fatal injury over the preceding year. One hundred and thirty five farm operators reported work related injuries in the preceding year with the cumulative incidence rate for any farm work related injury being 6.9%, or a mean of 8.2 farm work related injuries per 100 farmers in the preceding year. Multiple injuries in the same individual occurred more frequently than chance. Sprains and strains accounted for the most common injury in the back (29.4%) with overexertion was the most common external cause (24.5%); machinery related injury accounted for fourteen percent (14.3%); falls accounted for thirteen percent (13%); and animal related injury accounted for twelve percent (12.4%). Increasing reported total hours

worked on the farm in the preceding 12 months was significantly associated with an increased risk of injury suggesting a dose-response relationship (McCurdy et al 2004).

9.8 Workload and work pace and work practices and musculoskeletal conditions

Research exploring the relationships between workload, work pace and musculoskeletal conditions was conducted in the United States, the United Kingdom and New Zealand in this period.

9.9 Summary of Studies

- In the United States a cohort study showed risk factors increased with high work pace and workload (Hartmann et al 2006). A prevalence survey found factors associated with farm-work related injury included increased annual hours worked on farm, low levels of administrative work and increased time working with animals (McCurdy et al 2004). A prevalence survey in Iowa found those with additional non-agriculturally related employment were amongst those that experienced highest risk of back pain (Park 2001) Back pain was more prevalent amongst farmers than the general population and higher rates were found amongst Kansas farmers; which may be related to soy and corn production practices (Rosecrance & Merleno 2006). An observational study was conducted in the United States and explored a range of activities in apple harvest work, finding that this work is high risk ergonomically (Earle-Richardson et al 2004).
- A study in the United Kingdom found the highest rates of injury were as a result of handling, lifting, and carrying (4.9/1000 person-years)(Solomon et al 2007)**.**
- In New Zealand an observational study found shearers appeared to lose lumbar extension, gain hip flexion and develop an adaptive normal stance whilst shearing. These adaptations appeared to be independent of previous or current back pain. Lumbar extension loss in the non-shearers correlated with previous back injury. The researcher observed occupation is the predominant influence on motion and posture, followed by age (Milosavljevic 2005), with shearing having one of the highest rates of injury risks for rural occupational groups**.**

10.0 The studies

Hartmann et al (2006) cohort study of 86 sick leave claimants for neck/shoulder/upper extremity problems and 198 for back trouble were compared with 816 controls that made no claim in the same period. Multivariate analysis showed that risk factors increased with high work pace and workload.

A prevalence survey of 1947 farm operators in the United States explored self-reported non-fatal injury over the preceding year. One hundred and thirty five farm operators reported work related injuries in the preceding year with the cumulative incidence rate for any farm work related injury being 6.9%, or a mean of 8.2 farm work related injuries per 100 farmers in the preceding year. Multiple injuries in the same individual occurred more frequently than chance. Sprains and strains were the most common in the back (29.4%) and overexertion was the most common external cause (24.5%). Machinery related injury accounted for fourteen percent (14.3%); fall related injury accounted for thirteen percent (13%); and animal related injury accounted for twelve percent (12.4%). The factors associated with farm work

related injury included: white ethnicity, increased annual hours worked on farm; low levels of administrative work; increased time working with animals. The researchers concluded the multiple injuries to individuals suggested an interaction of personal and environmental risk factors (McCurdy et al 2004).

Park et al (2001) prevalence survey of 287 Iowa male farmers in the period 1992 to1994 explored self-reported lower back pain over the last twelve months. Thirty one percent of farmers reported daily back pain for a week or more during the past 12 months, compared to 18.5% in the general working population. Middle aged farmers and those with additional non-agricultural employment had the highest risk of back pain (Park 2001).

A prevalence survey of 499 active farmers in Kansas explored self-reported back pain over the previous 12 months and considered both exposure and risks. Of the 499 farmers contacted there was a 57.2% response rate. Lower back pain was the most prevalent (37.5%); followed by shoulder pain (25.9%); knee pain (23.6%) and neck pain (22.4%). Close to sixty percent of participants experienced back pain in at least one of the nine body areas in the previous year. Nearly a quarter of the participants saw a medical practitioner about their back pain; and one in five had to modify their work practices due to low back symptoms in the last year. Kansas farmers had higher rates of low back pain compared to the general working population and other farmers in other regions. This may be linked to the type of production which in this area is predominantly soybean and corn growing (Rosecrance & Merleno 2006).

Earle-Richardson et al (2004) adapted Posture-Activities-Tools-Handling (PATH) instruments and methods and conducted an ergonomic job analysis of apple harvest work in three New York orchards. The most frequently observed activities were picking, placing and moving apples in the bag, walking and weight bearing was observed 78.5% of the time through a range of activities. Researchers concluded that apple harvest work is comparable with other ergonomically high-risk occupations.

Solomon et al (2007) conducted a prevalence survey of 10 765 male participants in Britain and recorded life time histories of work in agriculture and occupational injury for men born in the period 1933 to1977. The incidence of injuries in agriculture reported in this study, were higher than those reported to statutory bodies amongst the self employed farmers. The highest rates of injury were as a result of handling, lifting, and carrying (4.9/1000 person-years); from falls from heights (4.6/1000 person-years); and injury by animals (3.4/1000person-years). The risk of injury for men was elevated when they had only recently entered agriculture and for those who also carried out forestry (Solomon et al 2007).

Milosavljevic et al (2005) on-site observational study involved 64 shearers and 64 non-shearers, in New Zealand and observed posture while shearing and considered present and previous back pain amongst participants. Shearers appeared to lose lumbar extension, gain hip flexion and develop an adaptive normal stance. This adaptation appeared to be independent of any association with previous or current back pain. Lumbar extension loss in the non-shearers correlated with previous back injury. The researchers observed that this occupational category with a very heavy work classification was the predominant influence

on observed differences in motion and posture, followed by age. The authors suggest that such sustained physical loads in prolonged flexion lead to structural adaptation at least in the lumbar spine and hips. Although there was no association between postural changes and a previous back pain injury this work force (shearers) carry one of the highest rates of injury risk for rural occupations in Australia and New Zealand (Lawrance 2005) and future research will require a cohort study to determine the relationships between work experience, adaptive change and injury risk.

10.1 Farm environment

The search found two studies that considered the farm environment and environmental risks of fatal and non-fatal injury.

10.2 Summary of studies

- In Australia an analysis of routine data found dams and bodies of water on farms to be significant environmental risks for fatal injury by drowning of children (1989-1992) (Mitchell et al 2001).
- In the United States a prevalence survey identified multiple injuries to individuals which researchers suggested were a result of interaction between personal and environmental risk factors (McCurdy et al 2004).

10.3 The Studies

Mitchell et al (2001) analysis of routine data exploring fatal injury amongst children in the period 1989 to 1992 in Australia revealed an average of 29 deaths per year and that dams and bodies of water are the most common location of injury and fatality (through drowning) on farms. Additionally, males were more commonly injured than females and children aged less than five years represented the majority of injury cases.

A prevalence survey in the United States explored self-reported non-fatal injury over the preceding year. Multiple injuries to individuals suggested to the researchers that there was an interaction between personal and environmental risk factors. For example, white ethnicity, hours of work, increased time working with animals and low levels of administrative work were associated with farm injury amongst the 135 farm operators in this study (McCurdy et al 2004).

10.4 Farm residence

Only one study was found that considered injury exposures and outcomes for those who reside on the farm and one study explored mortality and morbidity for non-resident farm workers.

10.5 Summary of study

- In Australia an analysis of farm related injury cases revealed that most of the victims were men who were employed and resident on the farm (Franklin and Davies 2003).

10.6 The Study

An analysis of 384 farm related injury cases in New South Wales, Australia revealed a rate of 34 injuries per 100 farms. In the majority of cases the victims were men who were employed

and resident on the farm and engaged in meat cattle, cereal and or poultry production. The common mechanisms of injury were horses, motorcycles, other animals and other objects (Franklin and Davies 2003).

10.7 Non-resident farm workers

One study in the United States analysed mortality and morbidity for workers in agriculture.

- A study in the USA analysed mortality and morbidity amongst all workers in agriculture and identified a fatality rate of 22/100 000 workers in the 1990s. Tractor incidents were the leading cause of death (300 per year) and non-fatal injuries amongst agricultural workers decreased in this period. The estimated injury rate for workers was 16.6/100 workers and high rates of musculoskeletal and respiratory symptoms, skin disorders and hearing loss were common. The over-all cancer rate was lower that other occupational groups, but specific cancers were found to be elevated in farmers. Researchers noted that the surveillance methods have not improved over the last decade and that the data on self employed farmers and their families is largely inadequate. The researchers also observed that there was a need to more specifically identify the populations at risk, for example: farmers and ranchers, migrant and seasonal workers (Rautianen et al 2007).

10.8 Crop or work activities

Injury specific to crop related work activities were the focus of two studies in this period, both in the United States.

- One study was found that considered fatality rates for people less than twenty years of age in the crop production sector (Hard et al 2006)
- Fatal entrapments in on-farm grain storage bins were considered by researchers in the period 1966-1998 in the United States (Kingman et al 2001).

10.9 The Study

Hard et al (2006) analysis of data from a census of occupational injury in the USA focused on 310 work related deaths to young people (<20 years old) in agriculture between 1992 and 2002. In this period there was a gradual downward trend in fatalities, but rates were higher for young workers in agriculture than young people in other sectors by a factor of 3.6 with fifteen year olds having the highest fatality rates and the crop production sector having a rate six times that of all 15 year old workers.

Kingman et al (2001) reviewed the Purdue University database to identify fatal entrapments in on-farm grain storage bins in the period 1966-1998. The fatalities were mainly in association with corn production, with the study also identifying fatalities in Canada – in Ontario. There were many more close calls or near misses documented. In those cases where the age of the victim was known 24% of the victims were aged between 3 and 15 years of age. Those younger than 16 suffocated primarily in June, while older victims suffocated in November, December, January, February and March. The high number of children dying in storage bins is cause of concern. Unloading grain was a significant high risk activity. Where gender as identified, males accounted for 96% of the fatalities.

11.0 Seasonal and temporal factors

Seasonal and temporal factors were considered by researchers in the United States and in Australia in relation to driveline related injuries and drowning.

11.1 Summary of studies

- In the United States driveline related injuries amongst youth occurred most commonly in the autumn (Beer et al 2007 and Beer et al 2007b)
- In Australia, fatal drowning amongst children most commonly occurred in spring, summer and on weekends (Bugela and Franklin 2005).

11.2 The Studies

An analysis of injury outcomes from drive line related incidents data in the United States, between 1970 and 2004, focused on injury outcomes for 151 young people (those under 18 years of age). This age group made up one in four of all documented agricultural driveline incidents. Serious injuries included amputation (in 50% of cases); spinal cord injuries and compound bone fractures. The trend in documented cases was declining with no fatalities recorded in 2004. Male youth were the most vulnerable (13 years) and had the highest frequency of incidents and over fifty percent of cases occurred to young people aged between 12 and 17 years. Most incidents occurred in the autumn and most frequently involved augers, elevators and conveyor machines (Beer et al 2007).

In another study Beer et al (2007b) analysed drive line injury outcomes for young people (those under 18 years) between 1970 and 2000. The following patterns were observed: drive line related injury declined in the 1990s and into the 2000s and 11-15 year olds had the highest frequency of cases with incidences most commonly happening in autumn. As with the previous study, augers, elevators and conveyors were the most common mechanism of injury.

Researchers analysed a routine data set with records of fatal drowning in dams for 27 children aged 0-5 years in rural Australia. Fatalities occurred predominantly in spring/summer and on weekends and more often amongst males less than 24 months old; in dams within 300metres of the home and parental property; and in dams with inadequate fencing (Bugeja & Franklin 2005).

11.3 Specific Mechanisms of Injury

Livestock, machinery and falls from heights have been previously highlighted as the most important mechanisms of occupational injury on farms (Myers 1998; McCurdy 2000). The literature since 2000 demonstrates that falls and machinery continue to rank in the top three risk factors for fatal and non-fatal injury on farms in North America, Europe and Australasia.

11.4 Animals

11.5 Summary of studies

- In the USA Parker et al (2001) cohort study of 290 principal farm operators in Iowa revealed hours working with animals and depressive symptoms were associated with incidence of farm-work related injuries. In another cohort study, amongst a range of results, significant associations were found between farm-work related injury and the

presence of large livestock (Sprince et al 2003). A third cohort study found significant associations between animal related injury and the use of a hearing aid; if the individual had medically diagnosed arthritis or rheumatism; and where a person had an education beyond high school level and was of a younger age (Sprince et al 2003). Farm women were more at risk of injury if there was a presence of large animals on the farm (Carruth 2002) and Hubler (2002) found Amish children were at significant risk of injury from livestock. An analysis of paediatric trauma cases revealed 41% of the children were injured by farm animals (Little et. al. 2003) and a prevalence survey found the most common mechanisms of injury were: horse related and cattle related. Females were more likely to be injured by horses when riding recreationally and the majority of males were injured by cattle while working. One out of five youth injuries on farms in the USA were animal related (Hendricks et al 2001) and increased time working with animals was found to be a factor related to farm-work related injury (McCurdy et al 2004).

- In the United Kingdom, tagging calves and clipping cattle was identified as a practice with significant risk of injury (Lindsay et al 2004). Additionally, a high risk of injury was identified for farmers handling animals in the United Kingdom (Solomon 2007).
- In Australia, higher injury rates were reported in the sheep sector and during livestock management/handling (Mather and Lower 2001). While horse related injuries occurred predominantly in females while mustering, or riding for leisure, for males, horse related injuries were more prevalent in older age groups and occurred while working (Davies and Franklin 2006). Men were identified as being at greatest risk of injury when employed and resident on the farm and engaged in meat cattle, cereal and or poultry production and the most common mechanisms of injury were horses, motorcycles, other animals and other objects (Franklin and Davies 2003).

11.6 The Studies

Parker et al (2001) cohort study of 290 principal farm operators in Iowa revealed that amongst these participants' hours working with animals and depressive symptoms were associated with the incidence of farm-work related injuries. Another Iowa cohort study established a significant association between farm work-related injury and the presence of large livestock (Sprince et al 2003)

Amongst the same cohort Sprince et al (2003) indentified 116 farmers with large livestock who had animal related injury requiring medical intervention in the last year and compared these farmers to 345 farmer controls. Multiple logistic regression analysis showed significant associations between animal related injury and the use of a hearing aid, medically diagnosed arthritis or rheumatism; education beyond high school level and a younger age.

A cross sectional study of 1096 farm women in Texas and Louisiana found factors predictive of increased risk of injury by multiple regression analysis included the presence of large animals (Carruth et al 2002). In another cross-sectional study of 4495 beef and dairy farmers in Scotland researchers considered all injuries relating to dairy and beef cattle. Bruising was the most common injury, followed by lacerations and fractures. Twenty percent of those with tagging related injuries lost time from work (a median of three days) and seventeen percent

reported clipping related injuries with a median of four days lost time from work. Tagging injuries most commonly affected the lower limbs and trunk, while clipping injuries most commonly affected the upper limbs. Tagging injuries most commonly occurred when working alone, in an open field and with a vehicle nearby. Clipping injuries were associated with working alone, with beef cattle and with younger age. Researchers concluded that tagging calves and clipping cattle prior to slaughter was associated with significant risk of injury and questioned whether this practice was necessary (Lindsay et al 2004).

In Australia cross sectional study of 506 farms, covering all production types, explored self reported injury in the preceding two years. Higher injury rates were reported in the sheep sector and during livestock management/handling (Mather and Lower 2001).

An analysis of a routine data set with records of horse and motorbike injury presentations at one hospital in Australia revealed that horse related injuries occurred predominantly in females while mustering, or riding for leisure. For males, horse related injuries occurred when riding for work and in older age groups (Davies and Franklin 2006).

Hubler (2002) study of 89 injuries amongst Amish children over a period of five months presenting at a hospital revealed five fatalities, sixty four injuries sustained by male children and 25 injuries sustained by female children. Falls were the most common mechanism of injury, followed by incidents involving livestock and both incidents most commonly resulted in orthopaedic surgery.

Little et al (2003) analysed 1832 paediatric trauma cases and found 94 were children with farm related injuries. The mean age was 10.75 years and the mean Injury Severity Score (ISS) was 7.38 and three children died. The mechanisms of injury included: animals (41%); falls (34%); motor vehicles (28%); all terrain vehicles (20%); and firearms (4%).

An analysis of 384 farm related injury cases in New South Wales, Australia revealed a rate of 34 injuries per 100 farms. In the majority of cases the victims were men, who were employed and resident on the farm and engaged in meat cattle, cereal and poultry production. Common mechanisms of injury were horses, motorcycles, other animals and other objects (Franklin and Davies 2003).

A review of 96 children presenting to hospital for injury in the United States over a period of nine years revealed that forty percent of the injuries were animal related and that Amish children had an increased risk of horse-related injury (38.5%) (Smith et al 2004).

A prevalence survey in the United States of 2000 ‘racial’ minority farms considered non-fatal injury risk and exposures and found that twenty eight percent of the youth on these farms rode horses. On the Hispanic farms there were 17 999 household youth and 30% of these youth rode horses (Hendricks et al 2005).

Hendricks et al (2001) prevalence survey of 26 000 farm households in the United States explored non-fatal animal related injury for youth. The survey identified 6 438 animal on-farm related injuries to youth in 1998. The most common mechanisms of injury were: horse related (37%) followed by cattle related injury (31%). The majority of horse related injuries

occurred to females and were non-work related and most of the cattle injuries occurred to males and were work related. One in five youth injuries on farms in the USA were animal related.

Another prevalence survey of 1947 farm operators in the United States explored self-reported non-fatal injury over the preceding year, of the 135 farm operators with reported work related injuries in the preceding year twelve percent of injuries were a result of working with animals (McCurdy et al 2004).

Solomon et al (2007) survey of 10 765 male participants in Britain recorded life time histories of work in agriculture and occupational injury for men born in the period 1933 to 1977. It was established that the injury by animal rate was 3.4/1000 person-years.

11.7 Agricultural machinery

The research record since 2000 continues to demonstrate that agricultural machinery is an important mechanism for injury for those working on the farms.

11.8 Summary of studies

- In the United States researchers found significant associations between machinery related injury and hours per week spent on farm work; fewer years farming experience; wearing a hearing aid and a high CAGE score indicating problem drinking (Sprince et al 2002). In another study (Sprince et al 2003) found that wearing a hearing aid was signficiantly associated with an increased risk of farm work related injury in the previous twelve months. Machinery related injury was also identified as a significant risk (McCurdy et al 2004). For youth farm fatalities, machinery was identified as a significant mechanism (Goldcamp et al 2004) and amongst children, tractors and other machinery were identified as significant mechanisms in fatal and non-fatal injury (Meiers 2001, Meyers 2001). Machinery related hospitalization rates were lower in British Columbia than in other parts of Canada, however, there were high rates of hospitalization for non-machinery related injury for young adult BC farmers (Saar et al 2006).) In Canada agricultural machinery ranks in the top three risks and outcomes for injury across all age groups (Bancej 2000; Dimich and Ward 2004). Another US study assessed auger-related injuries and farmers' perception of auger related injuries (Schwab et al 2000). Another study demonstrated that operators of conventional grain augers and gravity flow grain wagons have significant exposure to injury and high injury rates (Wilkinson & Field 2005). A study in the United States considered farm related limb amputations in children and found all cases considered involved injury from machinery where the child was "in the vicinity" rather than operating the machinery (McClure et al 2005).
- In New Zealand machinery and motor vehicles were amongst the most common mechanisms for injury (Horsburgh 2001).

11.9 The Studies

In Canada a cohort study of 1 765 family operated farms exploring all injury revealed that machinery (and falls) consistently ranked in the top three risks and outcomes for injury across all age groups (Bancej 2000).

Sprince et al (2002) cohort study in Iowa identified 205 farmers who had had machinery related injuries requiring medical assistance in the last year and compared these farmers to 473 farmer controls with no injury in the last year. Multiple regression analysis showed significant associations between machinery related injury and the more hours per week spent on farm work; fewer years farming experience; wearing a hearing aid and a high CAGE score indicating problem drinking.

Another study by Sprince et al (2003) examined risk factors for farm work related injury in the Agricultural Health Study. Multivariate analysis showed that wearing a hearing aid was significantly associated with an increased risk of farm work related injury in the previous twelve months (OR 2.36, 95% CI 1.07 – 5.20).

An analysis of 726 cases of farm related injury in Canada (Dimich-Ward 2004) established that regardless of how the injury occurred there were a greater number of males' injured (665 males to 61 females) and this was particularly so when farm vehicles was involved. The main mechanisms for fatal injuries included vehicle roll over (32%) for males and vehicle run over (45%) for females and more males over the age of 60 years had farm related injuries.

Schwab et al (2000) examined 437 records from the Iowa Department of Health relating to auger related injuries and found the most likely body part to be injured was the finger at 11.00am, 3.00pm and 5.00pm. The researchers also conducted a survey of 400 farmers to ascertain how aware they were of auger related injury and to determine the condition of their augers. Their perceptions coincided with injury records, however 34% of the primary and secondary augers were unshielded or without guarding.

A study of farm related limb amputations in children was conducted through retrospectively reviewing patient records for the period 1978 and 1992. Two hundred and fifty-nine cases of children who had traumatic amputations were identified, of these 11 met the criteria for this study. The criteria included being aged between 0-16 years of age, sustaining a traumatic, farm-related limb amputation (proximal to the tarsal and carpal bones). All of the cases were children who were not operating machinery but were "in the vicinity" of machinery (McClure et al 2005).

Goldcamp et al (2004) analysis of fatalities of young people on farms in the USA considered occupational and non-occupational fatalities in the period 1995 to 2000. The annual average farm fatality rate was 9.3 fatalities per 100 000 young people. Males accounted for 80% of the fatalities and the causes of death included machinery (25%), motor vehicle (17%), death by drowning (16%), death from suicide (8%); and death from homicide (6%).

An analysis of fatal injury data for agricultural workers in New Zealand aged 15-84 years in the period 1985-1994, revealed a rate of 21.2/100 000 for male agricultural workers. Injury

related deaths in the agricultural sector accounted for nearly a quarter of all work-related deaths in New Zealand with the most common mechanisms being machinery and motor vehicles, with vehicle overturns being the most common event (Horsburgh et al 2001).

Meiers (2001) analysis of trauma centre referrals between 1989 and 1998 explored fatal and non-fatal injury amongst children and youth. Twelve of the fourteen deaths (84%) involved tractors or machinery and the non-fatal injuries included: orthopaedic (56%); neurologic (42%); and thoracoabdominal (22%) with thirteen percent of the injuries resulting in long term disability. Seven of the fatalities involved solitary head injuries.

An analysis of fatal injury for young people aged 16 to 19 years in the United States in the period 1982 to 1994 revealed 550 on farm fatalities and that forty percent of these deaths were occupationally related. The leading causes of death were machinery related injury (54%) followed by death from electric current (20%). In the period 1991 to 1994 drowning and firearms accounted for the same number of on farm deaths as machinery related (Myers 2001).

An analysis of non-fatal and fatal injuries in agriculture in British Columbia, Canada in the 1990 to 2000 period, revealed 82 fatal injuries from 1990 to 2000; 1407 hospitalisations 1991/92 to 1999/2000. There was no significant overall incidence trend in this period. The machinery related hospitalization rate was lower in British Columbia than in other parts of Canada, but the rates of hospitalization for non-machinery related injury for young adult BC farmers were high (Saar et al 2006).

A prevalence survey of 1947 farm operators in the United States explored self-reported non-fatal injury over the preceding year. Amongst the 135 farmers machinery related non-fatal injury accounted for fourteen percent of all injury (McCurdy et al 2004).

Exposure to conventional grain augers while unloading from trucks and wagons; extended dump hopper augers, and swing away augers, was observed by researchers in the USA. Operators had higher exposure time to operating PTO components when the driveline was located on the right side of the grain auger, as one stands facing the hopper end of the auger; than they did on the left side of the auger when using conventional grain augers and grain trucks. This added exposure was due to the position of the driver's door of the truck, the natural path of the driver from the operator's seat to the rear of the truck and the movement of the truck body into the workspace when tilted. The operators had the highest exposure when using conventional grain augers and gravity flow grain wagons. Operators had no recorded exposure time when operating swing-away hopper augers. The researchers recommended reconfiguring the way augers are incorporated into grain handling operations (Wilkinson & Field 2005).

12.0 Farm vehicle injuries on public roads

One study addressed tractor related crashes and changes in legislation in the United States.

12.1 The Study

An analysis of the effectiveness of a state law change in Wisconsin, explored tractor related crashes in the period 1994 to 2003. Researchers found that the tractor certification course did not cover the major factors contributing to youth tractor crashes on public roads. One

hundred and forty six tractor crashes involved operators younger than 16 years on highways. Since the passing of the Wisconsin Act 455, no significant change in the number of youth tractor crashes occurred, nor was there any reduction in the number of crashes where the youth operator was designated at fault (Marlenga et al 2006).

12.2 ATV related injury:

ATV related fatal and non-fatal injury is an issue in all three regions, with all three regions experiencing a significant increase in the use of these vehicles and comparable injury circumstances and outcomes. The search found six studies that explored the risk factors and injury outcomes related to ATV use on farms.

12.3 Summary of studies

- In the United States risk factors for young males included frequency of use and the number of people on the ATV (Jones 2005). In 2001, there were 2,246 non-fatal ATV related injuries to youth younger than 20 years on farms in the USA and most of the injuries resulted from the recreational use of ATVs. Many of the youths were not wearing helmets or were using ATVs that were not the recommended size for their age (Goldcamp et al 2006). In addition an analysis of paediatric trauma cases revealed that these cases included children injured by all terrain vehicles (Little et al 2003). In 2001 to 2003 it is estimated that 108 724 children aged 15 years and under were treated in hospital for non-fatal injuries sustained while riding ATVs. ATV related injuries increased by twenty five percent in this period. Eleven to fifteen year old males represented over half of the young riders. Children aged 0 to 5 years were more likely to have facial injuries; older children were more likely to have trunk, leg or foot injuries. Fractures were the most common diagnosis (Shaults 2005). Brison et al (2006) reviewed fatal injuries for children in Canada for the period 1990 to 2001 and found children falling when riding on vehicles (including ATVs) was significant amongst fatalities and preschoolers were at greatest risk of fatal injury. Researchers identified that significant exposure to ATVs amongst 'racial' minority youth in the US was a significant risk factor for these young people (Hendricks 2005). Another study in the US explored emergency department admissions for pediatric ATV related injuries in Illinois and found an increase in ATV related injury (Nelson et al, 2005)

12.4 The Studies

A cross-sectional study of 652 youths in agricultural training programmes throughout the state of Arkansas explored ATV behaviours, exposures and injuries for farm youth and compared these with non-farm youth. Sixty percent of the students had operated ATVs within the past month. Farm youth were more likely to be white, male, to own a 3 wheel ATV and to ride more often with a single rider. The risk factors included frequency of use and number of people on the ATV (Jones 2005).

An analysis of a routine data set for non-fatal injuries, occupational and non-occupational, for youths on farms in the United States explored the association between the use of ATVs and injury. There are 1.1 million young people estimated to live on farms in the USA and thirty six percent of these operated an ATV in 2001. Those younger than 16 years were more likely

to have operated an ATV than a tractor and in 2001, 2,246 non-fatal ATV related injuries occurred to those younger than 20 years. Seventy four percent of these injuries occurred to young people resident on the farm, with males accounting for 69% of these injuries and the majority of injuries occurring to young people aged 10-15 years. Most ATV injuries resulted from recreational use of ATVs (58%) and many occurred to youths who were not wearing helmets or using ATVs that were larger than the recommended size for their age (Goldcamp et al 2006). In another study researchers considered 1832 paediatric trauma cases and found 94 were children with farm related injuries with twenty percent of these injuries being ATV related (Little et al 2003).

ATV related hospital admissions of children aged 15 years and under were studied by Shaults (2005) in the United States. In 2001-2003 it is estimated that 108 724 children aged 15 years and under were treated in hospital for non-fatal injuries sustained while riding ATVs with ATV related injuries increasing by twenty five percent in this period. Eleven to fifteen year old males accounted for fifty two percent of Emergency Department visits and hospitalizations among young riders, under five year olds were more likely to have facial injuries and older children were more likely to have trunk, leg or foot injuries. Overall, fractures were the most common diagnosis (27% of Emergency Department visits and 45% of the hospitalizations). Researchers noted that current legislation does not effectively address rising ATV related injuries (Shaults 2005).

A case series study of emergency department pediatric admissions for ATV related injuries was conducted in Illinois. The researchers concluded that ATV related injuries in Illinois are increasing and that these results mirror national trends (Nelson et al 2005).

Brison et al (2006) reviewed fatal injuries for children in Canada for the period 1990-2001, drawing on an administrative data set. Fatal agricultural injury was substantially higher than that of all-cause, unintentional injury among Canadian children aged 1-6 years (14.9 v 8.7 per 100 000 person/years respectively). There was elevated fatal injury amongst boys. Seventy three percent of the injuries occurred at the worksite and were the result of three mechanisms; 1) being run over by machinery as a bystander (29%); 2) being an extra rider and falling from the machine (22%) and, 3) asphyxia due to drowning (23%). Of all children, preschool children were at greatest risk of fatal injury.

A prevalence survey in the United States of 2000 ‘racial’ minority farms considered non-fatal injury risk and exposures. Twenty three percent of the 28 600 young people resident on racial minority farms rode an ATV and twenty seven percent of the 17 999 young people resident on Hispanic farms rode an ATV (Hendricks et al 2005).

12.5 Motor cycle related injury

One cross sectional survey conducted in Australia and tow analyses of routine data also in Australia were found in this period.

12.6 Summary of studies

- A cross sectional survey of high school students from agricultural colleges in Western Australia found those who were self taught for riding a motor cycle were at greater

risk of injury, as too were those who rode at speed and only wore a helmet "sometimes" (Lower 2003). An analysis of routine data found motor-cycle injuries occurring predominantly with males when using two wheel bikes and while riding for leisure (Davies and Franklin 2006). Another analysis of routine data found the majority of motorcycle related injury cases were men, who were employed and resident on the farm and engaged in meat cattle, cereal and or poultry production (Franklin and Davies 2003).

12.7 The studies

A cross-sectional study of 325 high school students from agricultural colleges in Western Australia investigated agricultural motorcycle use and injury. The students were at greater risk if self taught OR 2.13 (0.99 to 4.76) and if taught by an adult at maximum speed 101 +km OR 4.53 (1.33-15.40) and if only wearing a helmet "sometimes" OR 4.10 (1.26 to 13.36) (Lower 2003).

An analysis of a routine data set with records of horse and motorbike injury presentations at one hospital in Australia revealed motorcycle injuries occurred predominantly with males, on two wheel drive bikes while riding for leisure. When 4wd were involved in injury the individual was more likely to be admitted to hospital (Davies and Franklin 2006). A further analysis of 384 farm related injury cases in New South Wales, Australia revealed a rate of 34 injuries per 100 farms. In the majority of cases the victims were men, who were employed and resident on the farm and engaged in meat cattle, cereal and or poultry production. Common mechanisms of injury were horses, motorcycles, other animals and other objects (Franklin and Davies 2003).

12.8 Tractor related injury

12.9 Summary of studies

- In the United States 9.6 events/1000 persons/year involve tractor related injury, with males being the most at risk (Carlson et al 2005). Researchers have identified musculoskeletal conditions associated with tractor use, including neck/shoulder and upper extremity and back problems when tractor use is greater than 1000 hours per year (Hartmann et al 2006). In addition, researchers have identified women as being at greater risk of tractor related injury when they had been taught how to drive a tractor by their husband and were reliant on their husband's knowledge. Women were also more likely to drive tractors without ROPS if tractor use was less than twelve days a year (Carruth et al 2002). In Kentucky, researchers determined overturn probability of death is 0.08, five times smaller than the NIOSH estimate of 0.40 (Cole et al 2006). The use of ROPS on tractors was more common on large farms and amongst households with higher incomes with between 120 to 130 deaths per year resulting from tractor overturns and few farmers having seat belts (Sanderson et al 2006). In the period 1992 to 1998 the leading cause of death was overturns on tractors accounting for 25.8 deaths per 100 000 workers (Marlenga et al 2006; Rautianen et al 2007) and in the period 1994 to 2003 there was no reduction in youth tractor crashes on public roads despite legislative changes (Marlenga et al 2006). On

New York farms tractor run-overs were identified as a leading cause of injury for children (Mason 2002); and more generally tractor related injury was identified as a significant mechanism of injury for children (Meiers 2001). Kentucky farm youth were also found to be operating tractors on public roads without ROPS and carrying extra riders despite recognition that this is hazardous (Browning et al 2001). In Canada, researchers identified bystander runovers involving tractors as a significant risk for children (Brison et al 2006) and in the USA racial minority youth are exposed to tractors and at risk of tractor related injury (Hendricks et al 2005).

- In New Zealand fatalities from tractor overturns were the most common injury event between 1984 and 1994 (Horsburgh et al 2001).
- In Europe, one study found no association between tractor use and low back pain (Toren et al 2002. Researchers established a risk of developing white finger from the vibration of tractors after 3 to 4 years of use, if using a tractor for 8 hours a day while tilling soil (Gorlia et al 2006).
- In Australia, a study found tractors were the most common mechanism of injury for older adults (Mitchell 2002).

13.0 The Studies

A cohort study of 3, 765 households in the USA revealed an overall injury rate of 9.6 events/1000 persons per year involving tractor related injury. There was an increased risk for males with prior injury experience and variance by age with the high risk group being men aged 35-44 years (Carlson et al 2005).

A national cohort study in Sweden of properties larger than 10 ha considered annual exposure to tractor driving, its distribution across different work practices and sought to establish associations with self reported low back and hip symptoms amongst participants. Annual exposure hours were 472 hours. While ploughing was the most time consuming operation no relation between this practice and low back pain or hip pain was established. Exposure by: age, gender, location, tractor-use and production type were recorded (Toren et al 2002).

A cohort study of 86 sick leave claimants for neck/shoulder/upper extremity problems and 198 claimants for back problems were compared to 816 non claims controls. Multivariate analysis showed that risk factors increased with tractor driving greater than 1000hours/year (Hartmann et al 2006).

A cross sectional study of 1096 farm women in Texas and Louisiana found factors predictive of increased risk of injury by multiple regression analysis included: hauling goods to market, and driving a tractor for more than fifty two days a year (Carruth et al 2006). The same study revealed that these women had generally poor tractor knowledge, relied on their husbands primarily for tractor instruction and knowledge about driving a tractor, engaged in a wide range of farm work involving tractor use and were less likely to drive a tractor with ROPS or an enclosed tractor if driving a tractor for less than 12 days a year (Carruth et al 2006).

A cross sectional study of 6063 Kentucky farms identified 551 (9.1%) tractor overturns. The injury outcomes for 443 overturns of non-ROPS tractors and the 89 ROPS tractors were: no

or minor injury (non ROPS 70.43%; ROPS 82.02%); outpatient treatment (non-ROPs 21.90%; ROPS 9.00%); hospital admission (non-ROPS 15.35%; ROPS 3.37%; temporary disability (non-ROPS 13.54%; ROPS 14.61%; permanent disability (non-ROPs 3.16%; ROPS 0.00%); and death (non-ROPS 5.42%; ROPS 1.12%). The percentage total is more than 100% as some patients who were treated as outpatients were subsequently hospitalized, disabled or died. The probability of death from overturn of a non-ROPS tractor (0.08) was five times smaller than the NIOSH estimate of 0.40 (Cole et al 2006).

Another study in Kentucky (Browning et al 2001) documented the extent of tractor driving amongst children living and working on farms. The researchers found that children and youth commonly operated tractors without ROPS on public roads, and took extra riders, despite knowing this to be hazardous. Farms with annual incomes greater than $10 000 tended to use youth for tractor operation for more days than other farms. Researchers recommended further research.

Sanderson et al (2006) conducted a cross sectional study of farmers in Iowa and investigated all tractor related injury and the presence of ROPS. On average participants in this study owned 3.1 tractors with the average age of tractors 27 years. Only 39% of the 665 tractors in this study had ROPS. ROPS equipped tractors were more common on large farms and with households with a higher income. Only four percent of the farmers reported having seatbelts. There are approximately 120-130 deaths/year in the USA associated with tractor overturns.

An analysis of USA fatal and non-fatal injury records from national and regional surveillance systems from 1992 to 1998 found 25.8 deaths per 100 000 workers and 7.5 non-fatal injuries per 100 workers. Fatalities showed some decline in the 1980s, and were steady in the 1990s. Tractors were the leading cause of death and this was mostly due to overturns. Older farmers were at highest risk of farm fatalities. Traumatic injuries were a major concern for youth living or working on farms (Hard et al 2002).

Horsburgh et al (2001) analysis of fatal injury data for agricultural workers in New Zealand (aged 15-84 years), in the period 1985 to 1994, revealed a rate of 21.2/100 000 for male agricultural workers. Injury deaths in the agricultural sector accounted for nearly a quarter of all work-related deaths in New Zealand. Those at higher risk included, older women (65 to 84 years). The most common mechanisms were machinery and motor vehicles, overturns being the most common event.

An analysis of the effectiveness of a state law change in Wisconsin, explored tractor related crashes in the period 1994 to 2003. Researchers found that the tractor certification course did not cover the major factors contributing to youth tractor crashes on public roads. Of the tractor crashes occurring on highways, 146 involved operators younger than 16 years. Since the passing of the Wisconsin Act 455, no significant change in the number of youth tractor crashes occurred, nor was there any reduction in the number of crashes where the youth operator was designated at fault (Marlenga et al 2006).

An analysis of fatal and non-fatal injury data for New York (USA) farms for children and youths aged 1 to 18 years; revealed 164 injuries of which 29 were fatal, 18 were disabling

and 55% occurred while working. Leading injury mechanisms were tractor run over (12); and overturns (11). Of those working 35% were under the "job appropriate age limits". Tasks including loading square bales, fieldwork trailed implements and feeding calves most commonly involved injury to young victims. Injuries involving non-powered wagons had the highest frequency of under-aged victims (82%). The researchers concluded that children on New York farms are being assigned tasks that are developmentally inappropriate (Mason 2002).

Meiers (2001) analysis of trauma centre referrals between 1989 to 1998 explored fatal and non-fatal injury amongst children and youth revealed 49 children under 19 years of age were injured. The mean age was 7.3 years, 14 of the 45 died and the male to female ratio was 2:1. Thirty-three percent (33%) of the children received tractor related injuries.

Recorded work-related injury rates in Australia for the periods 1982-1984 and 1989-1992 revealed rates were high for those aged 15 to 25 years and 55 years and over in agriculture, when compared to other industries. Tractors were the most common mechanism for injury amongst older adults (Mitchell et al 2002)

An analysis of mortality and morbidity amongst all workers in agriculture in the United States identified the fatality rate in the 1990s to be 22/100 000 workers. Tractor incidents were the leading cause of death (300 per year) (Rautianen et al 2007).

Brison et al (2006) reviewed fatal injuries for children in Canada for the period 1990-2001, drawing on an administrative data set. Fatal agricultural injury was substantially higher than that of all-cause, unintentional injury among Canadian children aged 1 to 6 years (14.9 v 8.7 per 100 000 person/years respectively). There was elevated fatal injury amongst boys and amongst the 73% of the non-fatal injuries occurring at the worksite being run over/and or falling from a vehicle, including tractors, presented the greatest risk of fatal injury.

A prevalence survey of 48 agricultural establishments in Australia measured noise levels at the ears of operators and bystanders, tractors without cabs were identified as noise hazards and a health problem that needs to be addressed (Depczynski et al 2005). Another survey in the United States of 2000 'racial' minority farms considered non-fatal injury risk and exposures and twenty three percent of the young people on these farms operated tractors. Of the 17 999 youth on Hispanic farms, twenty five percent operated a tractor (Hendricks et al 2005). Exposure to vibration while using tractors was subject to an on-site observation study, with results showing that ten percent of the workers were exposed to a risk of vibration that induced white finger disorder of the hands after relatively short periods (3 to 4 years) if they were using a tractor for eight hours a day while performing soil tillage and transportation at full load (Gorlia et al 2006).

13.1 Other machinery and hand tools

Studies that considered machinery and hand tools and injury were conducted in the United States, England, Scotland and Wales and Australia in the period of review.

13.2 Summary of studies

- An analysis of injury outcomes from drive line related incidents between 1970 and 2004 in the United States revealed male youth were the most vulnerable, with 13 year old males being most at risk. Most incidents happened in autumn and augers, elevators and conveyor machines were the most frequently identified mechanisms (Beer et al 2007). Another study considered driveline related injuries in the USA between 1970s and 2000s and established these injuries were most frequent amongst 11 to 15 year olds, again occurring most commonly in autumn with the most common mechanisms being augers, elevators and conveyor machines (Beer et al 2005). An analysis of fatal injury data in Florida revealed the leading cause of death for all age groups was machinery related and that adult males are more likely to die from farm machinery related injury than females (Liller and Lehtola 2000). In Canada, fatal injury data for children revealed the three most common mechanisms were: 1) being run over by machinery as a bystander 2) being an extra rider and falling from the machine and 3) asphyxia from drowning (Brison et al 2006).
- In England, Scotland and Wales a cross sectional study of men and women aged 16-64 years found hand transmitted vibration a risk in agriculture(amongst a number of industries) and that men were most at risk (Palmer et al 2000)
- In Australia, Mather and Lower (2001) undertook a cross sectional study of farms (covering all production types) found higher injury rates in the sheep sector and identified the primary mechanisms as vehicles and hand tools. A prevalence survey in Australia measured noise levels and identified primary hazards as firearms, tractors without cabs, workshop tools, small motors (chainsaws, augers and pumps), when manually handling pigs, working in shearing sheds, and working with heavy machinery. The use of firearms without hearing protection was identified as a priority that needs to be addressed on Australian farms (Depczynski et al 2005).

13.3 The Studies

A cross sectional study of 506 farms in Australia, covering all production types, explored self reported injury in the preceding two years. Higher injury rates were reported in the sheep sector involving the use of vehicles and hand tools (Mather and Lower 2001).

A cross-sectional study of 22 194 men and women aged 16 to 64 years in England, Scotland and Wales investigated hand transmitted vibration by occupation and industry. Industries where high 8 hour time weighted average root mean square accelerated levels A(8) rms were $>5ms^{-2}$ most often arose in construction, motor repair, manufacture of basic metals and agriculture with men across all occupations and industry groups identified as most at risk (Palmer et al 2000).

An analysis of a routine data set of injury outcomes from drive line related incidents in the United States, between 1970 and 2004 focused on injury outcomes for 151 young people (those under 18 years of age). This age group made up one in four of all documented agricultural driveline incidents. Serious injuries included: amputation in fifty percent of cases, spinal cord injuries and compound bone fractures. The trend in documented cases is declining with no fatalities recorded in 2004. Male youth were the most vulnerable (13

years) and had the highest frequency of incidents. Over 50% of cases occurred to young people aged between 12 and 17 years. Most incidents were in autumn and augers, elevators and conveyor machines were the most frequently identified mechanisms (Beer et al 2007). In another study by Beer et al (2005) injury outcomes from drive line related incidents in the United States between 1970 to 2000 were analysed and the following patterns were observed: drive line related injury declined in the 1990s and into the 2000s, eleven to fifteen year olds had the highest frequency of cases and incidences happened most commonly in autumn. Again the main mechanisms of injury were: augers, elevators and conveyors.

An analysis of fatal injury data for farmer and farm workers in Florida, in the period 1989 to 1998, revealed the leading cause of death was machinery for both children and adults. Adult males were more likely to die from farm related injury than adult females (Liller & Lehtola, 2000).

Brison et al (2006) reviewed fatal injuries for children in Canada for the period 1990 to 2001, drawing on an administrative data set. Being run over by machinery as a bystander and falling from machinery when riding as an extra rider were amongst the three main mechanisms for the majority of worksite injuries.

A prevalence survey of 48 agricultural establishments in Australia measured noise levels at the ears of operators and bystanders and found that small motors on for example chainsaws, augers and pumps were common noise hazards, as too was heavy machinery such as harvesters, bulldozers and cotton module presses (Depczynski et al 2005).

13.4 Noise

The search found four studies which considered noise exposure and hearing impairment amongst those working in agriculture.

13.5 Summary of studies

- In Poland a cohort study of 31 family farms identified risk of hearing impairment amongst males (Solecki 2003).
- A cross sectional study in New Zealand investigated noise exposure and inhalable dust exposure amongst farmers and found that noise was an important hazard for New Zealand farmers, but that dust was less of a hazard than in the case in the northern hemisphere as outdoor pastoral farming is the norm in New Zealand and inhalable levels are lower outdoors (Firth et al 2006). An analysis of an administrative data set revealed that there has been a six-fold increase in compensation claims (in the decade 1995-2005) for hearing loss made by those working in agriculture, fisheries, trades, machine operators and assemblers. Ninety five percent of the claimants were middle aged and older males (Thorne 2008).
- In Australia a prevalence survey identified noise hazards for workers on farms and identified a range of mechanisms, including tractors without cabs, firearms, workshop tools, small motors, heavy machinery and manually handling pigs (Depczynski et al 2005).

13.6 The Studies

A cohort study of 31 family farms in Poland considered risk of hearing impairment amongst males with results confirming that noise in the working environment of private farmers creates significant risk for loss of hearing (Solecki 2003).

A cross-sectional study identified a subsample of 586 farmers and investigated noise exposure and inhalable dust exposure and their relation to hearing and respiratory conditions. Median inhalable dust levels for arable farmers was 1.7mg/m3 with 0.7mg/m3 for sheep farmers (NZ standard 10mg/m3). Total daily noise exposure levels were 86.8 dB(A) for sheep farmers, and 85.7 dB(A) for mixed farmers (NZ standard 85 dB(A)). Noise is an important hazard for New Zealand farmers, dust less so based on inhalable levels as outdoor pastoral farming is the norm in New Zealand (Firth et al 2006).

In another New Zealand study Thorne (2008) reviewed an administrative data set for the period 1995-2006 exploring occupational noise related exposure and hearing loss. The researcher observed that the current data base in New Zealand is unreliable. Accident compensation data revealed a substantial increase in claims annually, 2823 in July 1995 to June 1996; to 5580 in July 2005 to June 2006 representing a six fold cost increase over this decade ($193.82M). Agriculture, fisheries, trades workers, machine operators, and assemblers accounted for 53% of new claims and most claimants are middle aged and older males (95%).

A prevalence survey of 48 agricultural establishments in Australia measured noise levels at the ears of operators and bystanders. Common noise hazards included: firearms, tractors without cabs, workshop tools, small motors (chainsaws, augers, pumps), manual handling of pigs, shearing sheds, older tractors with cabs; and heavy machinery such as harvesters, bulldozers, cotton module presses. Use of firearms without hearing protection was identified as a health priority that needs to be addressed (Depczynski et al 2005).

13.7 Falls

Fatal and non-fatal injury resulting from falls was the subject of investigation for nine studies and a number of risk factors were considered, including, age, health impairments such as arthritis and or hearing difficulties, working with animals and temporary seasonal work.

13.8 Summary of studies

- In the United States a cohort study of Iowa farmers revealed that aging and health impairments such as arthritis or hearing difficulties are risk factors for fall-related injuries (Sprince et al 2003b). An analysis of administrative data on the hospitalisation of Amish children revealed that male children were more at risk of animal and fall related injury (Hubler 2002). And an analysis of administrative data in both Canada and the United States focussing on fatal and non-fatal injury found fall injuries accounted for forty one percent (41%) of all fatal and non-fatal injuries. With ninety one percent (91%) of the falls relating to farm production and sixty one percent (61%) of the complex falls from heights occurring when the children were not working. Both hospitalisations and fatalities were over-represented amongst complex falls (Pickett et al 2007). A review of routine data over a period of nine years,

revealed that children were most at risk of animal related injuries; Amish children had an increased risk of horse related injury and falls from buildings or haylofts and were at risk of head injuries (Smith et al 2004). A prevalence survey of farm operators revealed that factors associated with farm work related injury included: white ethnicity, increased annual hours worked on the farm; low levels of administrative work; and increased time working with animals. In cases where there were multiple injuries reported over the last twelve months, researchers suggested that there appeared to be an interaction between personal and environmental risk factors (McCurdy et al 2004).

- In Greece and analysis of routine data found that migrant workers were more at risk of falls from high levels, head injuries and dislocations (Alexe 2003). In Poland falls were more prevalent amongst 13-15 year old males and occurred while working unattended and when assisting other adults at work (Sosnowksa 2007). In the United Kingdom researchers conducted a prevalence survey of farmers, born in the period 1933-1977, and recorded incidence of injury over a working life time. The highest rates of injury were as a result of handling animals, lifting and carrying animals and objects and from falling from heights. The risk of injury was elevated amongst those new to agriculture and those who also carried out forestry on their properties (Solomon et al 2007).
- In Australia an analysis of administrative data found that fall related fatalities were most commonly due to falls from horses, machinery/vehicles, natural features and stockyards; ladders, trees and fences (Franklin et al 2004)
- In New Zealand an analysis of accident compensation claims for slips, trips and falls amongst those engaged in dairy farming was conducted for the period 2000-2002.

13.9 The Studies

In the Iowa cohort study a subset of 79 farmers were identified with fall related injury and compared to 473 controls, with no injury over the previous twelve months. Significant associations were found between fall-related farm injury and age between 40 to 64 years; medically diagnosed arthritis/rheumatism, hearing difficulties; and taking regular medications. They concluded that aging and health impairments (such as arthritis or hearing difficulties) are risk factors for fall-related injuries (Sprince et al 2003b)

An analysis of data on unintentional farm injury recorded in a routine data base (surveillance) in Greece revealed distinct patterns of injury including migrant workers being more at risk of falls from high levels, head injuries and dislocations (Alexe 2003).

An analysis of hospitalizations of forty two farmers and farm workers for fatal-fall related injuries in Australia in the period 1989 to 1992 revealed that fall related fatalities were predominantly a result falling from the following: a horse, machinery and or vehicles and or from natural features and or stockyards. Hospitalisations resulted from falls from horses, machinery/vehicles and static falls from horses, ladders, trees and fences (Franklin et al 2004).

Hubler (2002) conducted a study of Amish children presenting to a hospital over a period of 5 months. Male children sustained 64 injuries, female children 25 injuries and there were five fatalities. Falls were the most common mechanism of injury, followed by incidents involving livestock. Both incidents most commonly resulted in orthopaedic surgery.

Pickett et al (2007) considered fatal and non-fatal fall related injury of children recorded in administrative data bases in Canada and the United States. There were 484 paediatric fall injuries accounting for forty one percent (41%) of the case series (484/1193). Twenty percent (20%) of the fall injuries were into the path of a moving hazard and were defined as complex falls. Ninety one percent (91%) of complex falls were related to farm production and sixty one percent (61%) of these complex falls were from heights and occurred when the children were not working. Fatalities and hospitalizations were overrepresented in complex falls.

Sosnowska (2007) analysis of non-fatal farm related injuries to young people drawing from an administrative data base in Poland revealed that 13 to 15 year old males falling while working unattended or whilst assisting in the work performed by adults were most at risk and these falls most commonly occurred while they were working inside and outside in summer.

A review of 96 children presenting to hospital for injury in the United States over a period of nine years revealed that Amish children had an increased risk of horse-related injury (38.5%); falls from buildings or haylofts accounted for twelve percent of the injuries (12.5%), head trauma was the result in 36.4% of cases and skull fractures for twenty four percent of the cases (Smith et al 2004).

A prevalence survey of 1947 farm operators in the United States explored non-fatal injury over the preceding year. One hundred and thirty five farm operators reported work related injuries in the preceding year with the cumulative incidence rate for any farm work related injury being 6.9%, or a mean of 8.2 farm work related injuries per 100 farmers in the preceding year. Thirteen percent of the injuries were fall related (McCurdy et al 2004).

Solomon et al (2007) prevalence survey of 10 765 male participants in Britain recorded life time histories of work in agriculture and occupational injury for men born in the period 1933 to 1977. The incidence of injuries in agriculture reported in this study, were higher than those reported to statutory bodies amongst the self employed farmers. Falls from heights amounted to 4.9/1000 person-years.

In Australia an analysis of administrative data found that fall related fatalities were most commonly due to falls from horses, machinery/vehicles, natural features and stockyards; ladders, trees and fences (Franklin et al 2004)

In New Zealand an analysis of compensation claims for slips, trips and falls for those engaged in dairy farming was conducted in the period 2000-2002. The researchers concluded that slips, trips and falls happened more frequently in the Waikato region, during periods of greatest dairy workload, in older age groups and in 28% of the cases those injured were women. Activities other than walking were being undertaken in 57% of cases. Slips were the

most common incident prior to a fall, injuries occurred most commonly on concrete and in the cowshed, yard, on steps or while dismounting a vehicle (Bentley & Tappin 2004).

14.0 Mental Health

The review search found one cohort study, one cross-sectional study and one analysis of routine data all of which considered the relation between mental health status and injury.

14.1 Summary of Studies

- A cohort study in the United States found depressive symptoms and working with animals to be associated with farm related injury (Parker 2001). A cross sectional survey in Ontario, Canada found that risk of farm injury increased with higher levels of stress and that risks were greater amongst women who also worked off-farm (Simpson 2004).
- In the United Kingdom, access to mental health professionals for those in rural communities has been identified as a risk factor associated with higher suicide rates amongst farmers (Gregories 2002).

14.2 The Studies

Depressive symptoms and working with animals has been found to be associated with incidence of farm work related injuries in a cohort study in the United States (Parker et al 2001). The relation between stress and injury in farming in Ontario, Canada was explored through a cross sectional survey which found that risk of farm injury increased with higher levels of stress. Risks were greater amongst women who also worked off-farm (Simpson, 2004). And research on suicide rates in the United Kingdom revealed that access to mental health professionals might be a factor in the disproportionate number of suicides amongst this occupational group (Gregories, 2002).

14.3 Policy, injury control and regulation

Two studies explored the relation between policy and injury control and outcomes.

14.4 Summary of studies

- In the United States researchers analysed a routine data set to explore the incidence of tractor related crashes in the period 1994 to 2004 after the passing of the Wisconsin Act 455 which addressed the use of tractors on public roads. No significant change in the number of youth tractor crashes occurred; nor was there a reduction in the number of crashes where the youth operator was at fault. Researchers noted that the tractor certification course did not cover the major factors contributing to crashes on public roads (Marlenga et al 2006).
- Research in Sweden considered fatal injury in farming and forestry in the period 1988 to 1997 and found fatality rates in farming appear to be increasing (unlike other occupational groups). Most of the injuries resulted because the worker or a fellow worker failed to follow rules and or recommendations (Thelin 2002).

14.5 The Studies

An analysis of the effectiveness of a state law change in Wisconsin, explored tractor related crashes in the period 1994-2003. Researchers found that the tractor certification course did

not cover the major factors contributing to youth tractor crashes on public roads. 146 tractor crashes involved operators younger than 16 years on highways. Since the passing of the Wisconsin Act 455, no significant change in the number of youth tractor crashes occurred, nor was there any reduction in the number of crashes where the youth operator was designated at fault (Marlenga et al 2006).

A researcher drew on fatal injury data for Swedish farming and forestry in the period 1988 to 1997 to explore work-related fatality rates and the relation between fatalities and adherence to regulations. It was concluded that the number of work related fatal injuries in Sweden are decreasing for all occupational groups with the exception of farming and forestry operations. In farming the rate is 11.6/100 000 and the trends appears to be increasing. Membership of occupational health schemes was lower than expected amongst victims. Most of the injuries resulted because the worker or a fellow worker failed to follow rules and or recommendations (Thelin 2002)

14.6 Summary and limitations of the literature addressing risk factors and exposures to fatal and non-fatal injury in agriculture

The review revealed risk, exposure and injury outcome varies by age, gender and ethnicity. Children and older age groups are at greater risk as are men (and adolescent boys and young boys) and migrant workers who are also members of ethnic minority groups in the country where they are working. This review demonstrates as do previous reviews that tractors, machinery (including other vehicles, e.g. ATVs), livestock and falls (from machinery and farm structures) continue to be the top three risk factors for those working in agriculture in these regions. With respect to the types of injury, fatalities are most likely to occur in relation to vehicle and or machinery injury and falls and head injuries remain significant for permanent disability and fatality in all three regions. The review also reveals that the use of and uptake of safety equipment designed to prevent injury (for example hearing loss, or falls from vehicles) is still an issue in this sector with evidence of resistance amongst agricultural workers (both wage workers and owner operators) and common responses indicating that the rationale for resistance is practicality and or potential obstruction whilst performing tasks. Musculoskeletal conditions remain significant as an injury outcome (sprains, strains, and broken bones), crushes from both animals and machinery and hearing loss (from large machinery, small engines) and poor uptake of hearing protection remain significant as are head injuries from roll over's (tractor and ATV related) and head injuries from falls.

More generally, there was a surprising lack of attention paid to environmental risk and exposure factors on farms, a lack of attention paid to specific categories of workers on farms, that is, a tendency to treat all agricultural workers as a homogeneous category, and hardly any attention given to the policy environment and how this does, might, could or should shape injury risk, exposure and outcomes for agricultural workers. With the exception of two studies there were also few studies that adopted observation as a component of their methodology and in connection with this very little attention given to technology design and use practices – which may assist in prevention of injury or conversely ensure that high rates of injury will continue with respect to some technologies.

With respect to issues surrounding the reliability of the studies covered in this review, the two most prevalent studies designs were analyses of routine data (34) and cohort studies (15) which were followed by cross-sectional surveys (16), prevalence surveys (9) and case series (4) and nested case control (2) and on-site observational studies (2). With respect to the analyses of routine data sets, some researchers in New Zealand, Australia and the United States raised issues with respect to the reliability of the data in the data basess they drew from. Other issues connected to these studies included problems surrounding both the nature of data collection (especially if reliant on self reporting), lack of comprehensiveness that was in part a consequence of a number of agencies being engaged in data collection on injury (resulting in both over-counting and undercounting) undercounting and underreporting for some groups engaged in agricultural labour (for example non inclusion of officially retired people who continue to work on farms and the non-inclusion of unpaid labour of family members). For these studies there is seldom an account of person time exposure and often these studies lacked a comparison group. Some studies relied solely on data from one hospital data base and where it would not be possible to generalise the results either within the region or nationally.

The majority of cohort studies were conducted in the United States, and although the most reliable study design (it is also more costly), these studies drew predominantly from the Agricultural Health Study (AHS) research conducted in North Carolina and research conducted in Iowa where production primarily involves livestock farming and cropping and where the terrain differs from other regions in the USA. There were no cohort studies conducted in Australasia in this period and only two in Europe. These studies nonetheless provide the best evidence for causal relationships between exposure, risk and injury outcome.

In all three regions cross sectional surveys were common, possibly because they are easier to conduct and are not as costly as cohort studies. Some of the limitations of these studies are that they almost without exception involved self reporting (only two involved a trained researcher seeking responses to a questionnaire face to face) and all were reliant on participant recall (with no cross checking via medical records and/or other independent accounts), thus both the problems connected to self reporting (confusion over what is required, leaving out responses etc) and recall bias are common to all of these studies. Invariably too, these cross sectional surveys focussed on one region/province and commonly did not involve a comparison group and many were not representative with respect to production types and/or response rates ensured that the results could not be generalised.

The prevalence surveys were similarly compromised particularly with regards to a lack of a comparison group, small and or inadequate sample size and focussed typically on exposure and risk but seldom noted injury outcomes. The case series studies generally relied on small samples, often focussed on cases presented to just one hospital and where the hospital was located in a region that was not comparable to other agricultural regions nationally. These studies were also compromised by the records kept at these hospitals (e.g. missing cases, lack of comprehensive records, key data missing etc).

Finally the onsite observation studies whilst limited in terms of representativeness were the only studies to provide data that wasn't solely reliant on what people recalled or said that they did. These studies also typically made recommendations with respect to changes either in technology or in actual farming practice.

14.7 Part Two: Disease in agriculture – risk, exposures and prevalence

Table 2 summarises the literature on agricultural disease published between 2000 and 2007 (see Appendix B).

14.8 Introduction

The exposures and risk of disease in the agricultural sector currently being researched and where researchers signal the need for further research involve: exposure to chemical, biological and physical agents. These include dust and organic materials in relation to respiratory disorders; pesticides, herbicides and insecticides and the associations with cancers, including: brain, prostate, breast and ovarian cancer, lymphohematopoietic cancers including non-Hodgkin's lymphoma; leukaemia and multiple myeloma. The physical agents include noise and the risk of hearing loss along with UV radiation and the risk of skin, including lip cancer. There may also be increased risks of certain cancers in some farming sectors, for example lip cancer amongst those who are dairying.

14.9 Gender/Sex

Researchers have addressed the risk of disease by sex for some exposures and some sex specific cancers, prostate for males and ovarian and breast cancer for females. Many exposures are gender specific, and a consequence of the sexual division of labour on many properties. For example, it is predominantly men who apply pesticides and mostly women living on properties where pesticides are applied who wash or handle the clothing of pesticide applicators and may be in close proximity of pesticide application sites on the farm.

15.0 Summary of Studies

- **Cohort Studies in the USA**. A cohort study in the United States explored the routine application of diazinon (an organophosphate insecticide) and its association with cancer risk. When life time exposure was used, as a quantitative exposure metric, increased risks for the highest tertile of exposure and significant tests for trend for lung cancer and leukaemia were observed. No other cancer site showed an association with diazinon for the highest tertile exposure. Researchers caution that these results are based on small numbers and that further research is necessary (Beane et al 2005). A cohort study of women (farmers' wives) with no history of breast cancer explored the association of pesticide use and cancer incidence. There was some evidence of increased risk associated with the use of 2,4,5-trichloro-phenoxypropionic acid (2,4,5,TP) and possible use of dieldrin, and captan. However, only a small number of the participants had personally used the pesticides and researchers advised that no firm conclusions could be drawn from this study. No clear association was found with farm size, or with washing clothes worn by pesticide applicators however, risk was slightly elevated amongst women whose homes were in close proximity of pesticide application areas. The researchers recommended further research (Engel et al 2005).

15.1 The studies

A cohort study of 23 106 male applicators in Iowa and North Carolina explored the routine application of diazinon (organophosphate insecticide) and association with cancer risk. Two quantitative exposure metrics were used: life time exposure days and intensity-weighted life time exposure days, a measure that incorporates probability of pesticide exposure with life time pesticide application and frequency. When life time exposure days were used, increased risks for the highest tertile of exposure and significant tests for trend for lung cancer and leukaemia were observed. No other cancer site showed an association with diazinon for the highest tertile of exposure. These results were based on small numbers and the researchers concluded that additional analyses were necessary (Beane et al 2005).

Engel et al (2005) cohort study of 30 454 women with no history of breast cancer in Iowa and North Carolina explored the association between pesticide use and breast cancer incidence among farmers wives. Participants responded to a self administered questionnaire on pesticide use and other exposure information. There was some evidence of increased risk associated with use of 2,4,5-trichloro-phenoxypropionic acid (2,4,5,TP) and possibly use of dieldrin, and captan, but small numbers amongst those who had personally used the pesticides precludes firm conclusions. No clear association was found with farm size or washing clothes worn for pesticide application, however, risk was modestly elevated for women whose homes were closed to areas of pesticide application. Researchers noted that further follow-up is necessary and that the study was limited by its reliance on self reported exposure information and the possibility of recall bias amongst participants.

15.2 Cancers

There were sixteen cohort studies conducted in the United States which addressed associations with various pesticides and cancer incidence amongst agricultural workers and their spouses. There was one cohort study conducted in Norway which explored exposure to immunosuppressive substances (including mycotoxins and pesticides) and lip cancer incidence.

15.3 Summary of studies

- **Cohort Studies in the United States**. All of the following cohort studies drew on the Agricultural Health Study Cohort (in Iowa and North Carolina). A cohort study of male pesticide applicators in Iowa and North Carolina explored the routine application of diazinon (organophosphate insecticide) and association with cancer risk. When life time exposure days were used as the quantitative exposure metric, increased risk for the highest tertile of exposure and significant tests for trend for lung cancer and leukaemia were found. No other cancer site showed an association with diazinon for the highest tertile of exposure. Results were based on small numbers and the researchers recommended further research (Beane et al 2005). Blair et al's (2005b) cohort study of pesticide applicators and their spouses in Iowa and North Carolina explored agricultural exposure and risk factors for disease linked to pesticide application and compared the cohort to the general population in these two states, the cohort had a low mortality rate overall for specific causes and a low rate of overall cancer incidence. However some cancers were elevated including: multiple myeloma,

cancers of the lip, gallbladder, ovary, prostate, and thyroid; however numbers were small for many cancers. Associations were found for prostate cancer and the use of several pesticides, especially when individuals had a family history of prostate cancer. Pesticide use and other agricultural factors were associated with injury, retinal degeneration and respiratory wheeze (Blair et al 2005b).

- A cohort study of pesticide applicators in the same states for the period 1993-1997 explored associations between Malathion (the most common organophosphate insecticide applied in the United States) and cancer amongst pesticide applicators. Life time days of malathion use (top tertlle of exposure, >39 days) was not associated with all cancers combined. Risk of non-Hodgkin's Lymphoma was not associated with malathion use. However the number of cases was small. Malathion use was not clearly associated with cancer. While rate ratios for melanoma were reduced, small numbers and the lack of experimental evidence suggested that these reductions may have arisen by chance (Bonner 2007). Bonner et al (2005) conducted another cohort study of pesticide applicators in the same states, explored exposure to carbofuran (a carbamate insecticide used for a variety of food crops, including corn, alfalfa, rice, and non food - tobacco) and its relation to lung cancer. The study found no association with lung cancer risk in non-exposed persons used as a referent. Carbofuran was not associated with any other cancer site examined. Researchers recommend cautious use of these results.
- De Roo et al (2005) conducted a cohort study of licensed pesticide applicators in the same states and explored associations between exposure to Glyphosate (a broad spectrum herbicide and one of the most frequently applied in the world) with cancer incidence amongst applicators. Glyphosate exposure was not associated with cancer incidence overall or with most cancer subtypes. There was a suggested association with multiple myeloma incidence and researchers recommended this be followed up as more cases occur in this study (Bonner et al 2005).
- Dinham et al (2005) cohort study explored associations between exposure to four of the most commonly used agricultural pesticides (diazinon, dieldrin, metalochlor and pendimethalin) and lung cancer. Researchers found significant increased risk of lung cancer amongst those with the greatest exposure compared with those with no exposure. Increased risk of lung cancer was found only for those with prolonged exposure to diazinon, dieldrin, metalochlor and pendimethalin (Dinham et al 2005). A cohort study of farmers wives with no history of breast cancer and possible association with pesticide exposure and breast cancer found some evidence of increased risk associated with use of 2,4,5, trichloro-phenoxypropionic acid (2,4,5,TP) and possibly use of dieldrin and captan, but numbers were small for those who had directly used these pesticides. No clear association was found with farm size or washing clothes worn for pesticide application; however risk was elevated modestly for women whose homes were close to areas of pesticide application. Researchers noted the need for further research (Engle et al 2005).
- Hou et al (2006) cohort study explored exposure to pendimethalin (herbicide) use among pesticide applicators and the incidence of cancer. There was no clear

association between pendimethalin use and risks of specific cancers. The risk for rectal cancer rose with increasing life time pendimethalin exposure when using the non-exposed as a reference group; but the association was attenuated when using the low exposed referent group. There was some evidence of elevated cancer risk for lung cancer, but only amongst highest exposure category for life time pendimethalin exposure. Overall, the researchers found no clear association of life time pendimethalin exposure either with overall cancer incidence or specific cancer sites.

- A cohort study of pesticide applicators in Iowa and North Carolina, using the Agricultural Health Study cohort, explored exposure to DDVP (2,2 Dicholoreothenyl dimethylphosphate) and incidence of cancer. There was no observed elevation of risk among lymphohematopoietic cancers and a small excess risk associated with exposure among those with a family history of prostate cancer. At this stage of the follow-up there was little evidence of an association between cumulative life time use of DDVP and risk of any cancer (Koutros et al 2008).
- Lee et al (2004) cohort study of licensed pesticide applicators in the same states explored exposure to alachlor and incidence of cancer amongst pesticide applicators. Among alachlor exposed applicators there was a significant increasing trend for incidence of all lymphohematopoietic cancers associated with life time exposure days (p for trend =0.02) and intensity weighted exposure days (p for trend =0.03) to alacholor. Risks of leukaemia and multiple myeloma were increased amongst applicators in the highest alachlor exposure category. A possible association between alachlor application and incidence of lymphohematopoietic cancers was found amongst applicators. A cohort study of pesticide applicators, also in Iowa and North Carolina, explored exposure to pesticides and incidence of colorectal cancer. Most of the 50 pesticides studied were not associated with colorectal cancer, however, chlorpyrifos use showed a significant exposure response trend for rectal cancer with an increased risk in the highest exposure category. Aldicarb was associated with a significantly increased risk of colon cancer. Dichlorophenoxyacetic acid showed a significant inverse association with colon cancer but the association was not monotonic. Researchers advised the results be treated with caution as there is to date a limited body of evidence that pesticides are related to colorectal cancer. However, their results suggest a possibility of an association between exposure to certain pesticides and incidence of colorectal cancer amongst pesticide applicators (Lee et al 2007). Another study in Iowa and North Carolina explored exposure to cyanazine and cancer incidence amongst pesticide applicators in these two states. No clear, consistent associations with cyanazine exposure and any cancer were found in this study. Researchers concluded the number of sites for certain cancers were small and this limited any conclusion that could be made about ovarian, breast and some other cancers (Lynch et al 2006).

  Using the Agricultural Health Study cohort (Iowa and North Carolina) researchers explored exposure to carbaryl (carbamate insecticide) amongst pesticide applicators and incidence of cancer. Carbaryl was not associated with cancer risk overall. Although not significant there appeared to be a trend of decreasing prostate cancer

risk with increasing level of exposure. A small increase in NHL risk was observed using some, but not all, exposure measures. No associations were observed with other examined cancer sites (Mahajan et al 2007). Another study drawing on the Agricultural Health Study cohort explored the association of phorate exposure with overall cancer incidence. Phorate use was not related to incidence in all cancers combined or to any individual cancer. However the study lacked sufficient numbers to study non-Hodgkin's lymphoma or leukaemia which have been linked to organophosphates in other studies. There was an increased risk of prostate cancer amongst those with a family history of prostate cancer (Mahajan et al 2006). Using the same cohort, researchers explored exposure to fonofos and risk of cancer. Relative to the un-exposed, leukaemia risk was elevated in the highest category of life time and intensity weighted exposure days. Risk of prostate cancer was not related to fonofos use overall, however, among applicators with a family history of prostate cancer a significant dose-response trend for life time exposure days was observed. Intensity weighted results were similar. No associations were observed with other examined cancer sites. Further research was recommended to confirm the findings with respect to leukaemia and to determine whether genetic susceptibility modifies prostate cancer risk from pesticide exposure.

- **A Norwegian cohort study** explored exposure to immunosuppressive substances (including mycotoxins and pesticides) and lip cancer incidence. Researchers found lip cancer to be moderately associated with the presence of horses on the farm; construction work employment; pesticide use; grain production; and increasing levels of fungus forecasts. Moderate associations of lip cancer with grain production and fungal forecasts and the negative associations with pesticide could possibly be explained by exposure to immunosuppressive mycotoxins. Some of the associations observed could be explained by solar exposure (Nordby et al 2004).

17 Case Control Studies

Seventeen case control studies were found, eleven in the United States, two in Australia, one in New Zealand, one in Germany, one in France, and one in Spain.

- In the United States a case control study in Iowa, Michigan, Minnesota and Wisconsin explored the relation between gliomas and farm pesticide exposure for women. Researchers found exposure to pesticides was not associated with an increased risk of intracranial gliomas in women. It was concluded that other farm related factors could be etiologic factors (Carreon et al 2005). Duell et al (2000) case control study explored the relation between farming exposures and breast cancer amongst women in North Carolina. The results showed a possible increased risk of breast cancer among a subgroup of farming women who are more likely to be exposed to pesticides. A nested-case control study of the relation between prostate cancer and the type of crop production was conducted in the USA. The cohort, were predominantly Hispanic and members of the labour union in California. It was concluded that Hispanic farm workers with relatively high exposure to organocholrine pesticides (lindane and

heptachlor), organophosphate pesticides (dichlovos), fumigants (methyl bromide), or triazine herbicides (simazine) experienced elevated risk of prostate cancer when compared to workers with lower exposure (Mills 2003). Ruder et al (2004) case control study of farm pesticide exposure and glioma risk in Iowa, Michigan, Minnesota and Wisconsin revealed no positive association and the researchers concluded that other farm exposures may explain the excess brain cancer risk amongst farmers (Ruder et al 2004). Samanic et al (2006) study investigated cancer incidence among pesticide applicators exposed to dicamba. Although associations between exposure and lung and colon cancer were observed, there was no clear evidence for an association between dicamba exposure and cancer risk. An investigation into whether exposure to animals or the public could result in exposure to infectious agents which might play a role in the aetiology of lymphohaematopoietic cancers found increased risks of Non Hodgkin's Lymphoma, Hodgkins disease, multiple myeloma and leukaemia with those occupations that involved animal exposure. However associations were confounded by other exposures and researchers recommended further exploration was necessary (Svec et al 2005). A meta-analysis of 22 studies conducted in the period 1966-2003 exploring the relationship between pesticide exposure and prostate cancer concluded that overall there was insufficient exposure information from the individual studies to provide any firm conclusions (Van Maele-Fabry 2004). A study evaluating the relationship between the use of organophosphate pesticides and non-Hodgkin's Lymphoma among white farmers found associations between the risk of Non-Hodgkin's Lymphoma and several groupings and specific organophosphate pesticides (Waddell et al 2001). An investigation of the risk of non-Hodgkin's lymphoma from exposure to carbamate insecticide amongst farmers suggested an increased risk of NHL was associated with carbamate insecticide use (Zheng et al 2001). Lee et al (2004) conducted an evaluation of the risk of stomach and oesophageal adenocarcinomas associated with farming and agricultural pesticide use. However, no significant associations were found between specific agricultural pesticide exposures and the risk of stomach or oesophageal adenocarcinomas. Another case control study evaluated the risk of adult glioma associated with farming and agricultural pesticide use in Nebraska and found significant associations between some specific agricultural pesticide exposures for male farmers with Odds Ratios significantly increased for the herbicides mertribuzin and paraquat and for the insecticides bufencarb, cholorpyrifos and coumaphos (Lee et al 2005).

- In Australia, a case control study conducted in two Australian states, explored occupational exposure to pesticides and risk of non-Hodgkin's lymphoma. Substantial exposure to any pesticide was associated with a trebling of risk of non-Hodgkin's lymphoma. Subjects with substantial exposure to organochlorines, organophosphates and "other pesticides" (excluding herbicides) and herbicides other than phonoxy herbicides had similarly increased risks, however, these were only statistically significant for "other pesticides" (Fitschi et al 2005). Another population based case control study in Western Australia explored the association of selected occupational exposures with risk of prostate cancer and with risk of benign prostatic hyperplasma (BPH). The researchers concluded the results did not provide evidence

that any of the occupational factors examined (pesticides, fertilisers, metals, wood dust, oils, diesel exhaust and polyaromatic hydrocarbons (PAHs)) were risk factors for either prostate cancer or BPH (Fitschi et al 2007).

- A New Zealand based case control study aimed to assess whether previously observed occupational associations with non-Hodgkin's lymphoma in New Zealand persisted. An elevated risk of NHL was observed for field crop and vegetable growers, and horticulture, and fruit growing; particularly for women. Sheep and dairy farming was not associated with any increased risk of NHL. Meat processors had an elevated risk, as did heavy truck drivers, workers employed in metal product manufacturing and cleaning. The elevated risks amongst those in horticulture, fruit growing and metal product manufacturing were the most robust findings of this study (t'Mannetje et al 2007).
- A case control study in Germany sought to identify occupations associated with malignant lymphoma. The researchers observed an increased lymphoma risk amongst architects, maids, farmers, glass formers and construction workers. Follicular lymphoma showed highly significant risk increases for several occupational groups, including veterinary workers. Multiple myeloma showed a particularly pronounced risk increase for farmers as well as for agricultural and animal husbandry workers (Mester et al 2006). In France researchers investigated the relationship between exposure to pesticides and brain tumours in adults. The data suggested that a high level of occupational exposure to pesticides might be associated with an excess risk of brain tumours, especially gliomas. And in Spain, researchers estimated the risk of lymphoma among farmers and found while farmers were not at an increased risk of lymphoma compared to other occupations, those who were exposed to non-arsenic pesticides had an elevated risk and particularly if exposed for more than nine years (Van Balen et al 2006).

Analyses of Routine Data

- An analysis of mortality data in the period 1989-1996 in the United States suggested an increased pancreatic cancer mortality among long term residents in areas of high application rates of 1,3 d (an EPA classified probably human carcinogen), captafol, pentacholoronitrobenzene (PCNB) and dieldrin (Clary 2003). An analysis of industry and occupation coded mortality data in the period 1984-1993 in the United States found among white, male, livestock farmers there were significantly higher mortality from cancer of the pancreas, prostate and brain, non-Hodgkin's lymphoma, multiple lymphoma, acute and chronic lymphoid leukaemia and Parkinson's disease. White, male crop farmers showed significantly higher mortality risk of cancer of the lip, skin, multiple myeloma, and chronic lymphoid leukaemia. This disease trend suggests that livestock farmers are exposed to more carcinogens or agricultural chemicals than crop farmers (Lee et al 2002). In Canada, an analysis of incidence rates of testicular cancer and the role of agricultural exposure for farmers and non-farmers found that farmers were significantly more likely than non-farmers to be diagnosed at

stage 2 or higher. Based on this data the significant predictors of being diagnosed with stage 2 testicular cancer were presence of nonseminoma in those less than or 26 years of age and those farming as an occupation (McDuffie et al 2007). Investigating incidence of breast cancer in areas of high agricultural pesticide use in California, researchers concluded this study provided no evidence that these women, living in areas of recent, high agricultural pesticide use experienced higher rates of breast cancer (Reynolds et al 2005). Researchers explored whether rates of lymphoprofliferative malignancies among children were elevated in areas of intensive agricultural pesticide use in the state of California. This study produced null results, which stand in contrast with existing epidemiological literature which suggests elevated childhood cancer in areas with reported household pesticide use. Researchers suggested that differences might be due to different chemical agents, different exposures both indoor and outdoor, or both. More research is needed in this area (Reynolds et al 2005).

- In Sweden, researchers identified cancer rates amongst the children of pesticide applicators born in the period 1965-1976. None of the a-priori hypotheses of increased risk of tumours of the nervous system, kidney cancer, leukaemia, lymphoma soft tissue sarcoma, and testicular cancer in children of male pesticide applicators could be confirmed (Rodvall et al 2003).
- In New Zealand, an analysis of the cancer registry for the period 2003-2004 confirmed that crop farmers and meat processing workers remain high risk occupations for non-Hodgkin's lymphoma (NHL) in New Zealand and also identified several other occupations and industries of high non-Hodgkin's lymphoma (NHL) risk that merit further study (t'Mannetje et al 2008).

15.4 The Studies

A cohort study of 23 106 male applicators in Iowa and North Carolina explored the routine application of diazinon (organophosphate insecticide) and possible association with cancer risk. Two quantitative exposure metrics were used: life time exposure days and intensity-weighted life time exposure days, a measure that incorporates probability of pesticide exposure with life time pesticide application and frequency. When life time exposure days were used, increased risks for the highest tertile of exposure and significant tests for trend for lung cancer and leukaemia were observed. No other cancer site showed an association with diazinon for the highest tertile of exposure. Researchers noted that the results are based on small numbers and that additional analyses are necessary (Beane et al 2005).

Blair et al (2005b) cohort study of 85 658 pesticide applicators and their spouses in Iowa and North Carolina in the period 1993-1997 explored agricultural exposure and risk factors for disease linked to pesticides and compared these to the general population of the two states. The cohort experienced a low mortality rate overall for specific causes and a low rate of overall cancer incidence. Some cancers did appear elevated, including: multiple myeloma, cancers of the lip, gallbladder, ovary, prostate, and thyroid, but numbers were small for many cancers. Some association was found with exposure to several pesticides and prostate cancer,

especially among individuals with a family history of prostate cancer. Pesticide use and other agricultural factors were linked to: injuries, retinal degeneration, and respiratory wheeze.

A cohort study of 19 717 pesticide applicators in Iowa and North Carolina, in the period 1993-1997, explored potential associations between Malathion (most common organophosphate insecticide applied in the USA and cancer amongst pesticide applicators. Information on life time years and days per year of use and intensity of malathion exposure was obtained through self-administered questionnaires prior to the onset of any cancer the follow-up was an average of 7.5 years (1993-2002) Rate ratios and 95% confidence intervals were calculated using Poisson regression with adjustments made for potential confounders. The results showed life time days of malathion use (top tertile of exposure, >39 days) was not associated with all cancers combined. The risk of non-Hodgkin's Lymphoma was not associated with malathion use - but the number of cases was small and the risk of melanoma with more than 39 life time exposure days was 0.39. In sum, malathion use was not clearly associated with cancer. The rate ratios for melanoma were reduced and the small numbers and lack of experimental evidence suggest that these reductions may have arisen by chance (Bonner 2007)

Bonner et al (2005) cohort study of 49 877 licensed pesticide applicators selected from the Iowa and North Carolina cohort explored exposure to carbofuran a carbamate insecticide used for a variety of food crops including corn, alfalfa, rice, and tobacco. Nitrosated carbofuran has demonstrated mutagenic properties. The researchers recorded information on years of use, the frequency of use in an average year, and when use began for 22 pesticides using self-administered questionnaires. Poisson regression was used to calculate rate ratios (RR) and 95% confidence intervals (CIs), adjusting for potential confounders. Lung cancer was three-fold higher for those with greater than 109 days of life time exposure to carbofuran; compared with those with less than nine life time exposure days, with a significant dose-response trend for both days of use per year and total years of use. Carbofuran was not associated with lung cancer risk in non-exposed persons who were used as a referent. Carbofuran was not associated with any other cancer site examined. Researchers advised that these results should be used cautiously as there was no a-priori hypothesis specifically linking carbofuran with lung cancer.

De Roos et al (2005) study of 57 311 licensed pesticide applicators selected from the cohort study in Iowa and North Carolina, explored associations between exposure to Glyphosate (a broad sprectrum herbicide and one of the most frequently applied in the world) and cancer incidence amongst licensed pesticide applicators. A self administered questionnaire recorded information on pesticide use and exposure was defined as a) ever personally mixed or applied products containing glyphosate; b) cumulative life time days of use or "cumulative exposure days" (years of use x days/year); and c)intensity-weighted cumulative exposure days (years of use x days/year x estimated intensity level). Poisson regression was used to estimate exposure-response relations between glyphosphate and incidence of all cancers and 12 relatively common cancer subtypes. Glyphosate exposure was not associated with cancer incidence overall or with most cancer subtype, but there was a suggested association with

mutiple myeloma incidence which researchers considered should be followed up as and if more cases occur in this study.

Dinham et al (2005) cohort study explored associations between exposure to four of the most commonly used agricultural pesticides (diazinon, dieldrin, metalochlor and pendimethalin) and lung cancer. The researchers found significant increased risk of lung cancer amongst those with greatest exposure compared with those who had no exposure. Exposure to three other pesticides: carbofuran, cholorpyrifos, and dicamba, was explored and results suggested an increased risk of lung cancer, however these results were not statistically significant. Increased risk for lung cancer was only apparent for those with prolonged exposure to diazinon, dieldrin, metalochlor and pendimethalin.

Engel et al (2005) cohort study of 30 454 women with no history of breast cancer in Iowa and North Carolina explored the association between pesticide use and breast cancer incidence among farmers wives. Participants responded to a self administered questionnaire on pesticide use and other exposure information. There was some evidence of increased risk associated with use of 2,4,5-trichloro-phenoxypropionic acid (2,4,5,TP) and possibly the use of dieldrin, and captan, but small numbers amongst those who had personally used the pesticides precluded any firm conclusions. No clear association was found with farm size or washing clothes worn for pesticide application, however, risk was modestly elevated for women whose homes were close to areas of pesticide application. Researchers noted that further follow-up is necessary and that recall bias was a limitation of this study.

Hou et al (2006) cohort study of 9 089 pesticide applicators selected from the Iowa and North Carolina study explored exposure to pendimethalin and incidence of cancer and compared with 15 285 nonpendimethalin-exposed pesticide applicator controls. The respondents completed two questionnaires, one on enrolment and one which they took home for completion. Poisson regression analysis was used to evaluate the association of pendimethalin exposure with cancer incidence (mean follow-up 7.5 years) using two exposure metrics: tertiles of life time days of exposure and tertiles of intensity-weighted life time days of exposure. Cancer incidence did not increase with increasing life time pendimethalin use and there was no clear evidence of an association between pendimethalin use and risks for specific cancers. The risk for rectal cancer rose with increasing life time pendimethalin exposure when using the non-exposed as the reference, but the association was attenuated when using the low exposed referent group. Similar patterns for rectal cancer were observed when using intensity-weighted exposure-days. The number of rectal cancer cases among the pendimethalin-exposed was small (n=19) and there was some evidence for an elevated cancer risk for lung cancer, but the excess only occurred in the highest exposure category for life time pendimethalin exposure and trends for lung cancer risk were inconsistent for different exposure metrics. Overall, the study did not find a clear association of life time pendimethalin exposure either with overall cancer incidence or with specific cancer sites.

Another study of 57 311 licensed pesticide applicators taken from the Iowa and North Carolina cohort in the period 1993-1997 explored exposure to DDVP (2,2 Dichloroethenyl

dimethylphosphate) among pesticide applicators. Researchers employed a questionnaire to collect exposure information on DDVP and potential confounders and 4,613 respondents reported using DDVP in this period. DDVP exposure was classified as intensity-weighted cumulative exposure days (IWED), calculated as [years of use x days per year x intensity level]. Poisson regression analysis was used to calculate rate ratios (RR) and 95% confidence levels (CI) to evaluate the association of DDVP exposure among 2 943 incident cases of cancer. DDVP exposure was not associated with any cancer in this study and there was no observed elevation of risk among lymphohematopoietic cancers, but a small excess risk associated with exposure among those with a family history of prostate cancer. Results revealed little evidence of an association between cumulative life time use of DDVP and risk of any cancer at this stage of the follow-up of the AHS study (Koutros SM et al 2008)

Lee et al (2004) study of 49 980 licensed pesticide applicators from the Iowa and North Carolina cohort (AHS cohort) explored exposure to alachlor and incidence of cancer amongst pesticide applicators. Pesticide exposure information and other information were obtained through a self administered questionnaire at the time of enrolment (1993-1997). Poisson regression analysis was used to evaluate the exposure-response relations between alachlor and cancer incidence and controlled for the effects of potential confounding factors. Among alachlor exposed applicators there was significant increasing trend for incidence of all lymphohematopoietic cancers associated with life time exposure days (p for trend =0.02) and intensity-weighted exposure days (p for trend=0.03) to alachlor. Risks of leukaemia and multiple myeloma were increased among applicators in the highest alachlor exposure category. A possible association between alachlor application and incidence of lymphohematopoietic cancers was found amongst applicators.

Another study by Lee et al (2007) of 56 813 pesticide applicators with no prior history of colorectal cancer in Iowa and North Carolina, in the period 1993-1997 (AHS cohort), explored exposure to pesticides and incidence of colorectal cancer. Pesticide exposure information was obtained through self administered questionnaires completed at the time of enrolment (1993-1997). Cancer incidence was determined through population-based cancer registries from enrolment through to 2002. Although most of the 50 pesticides studied were not associated with colorectal cancer risk, chlorpyrifos use showed a significant exposure response trend for rectal cancer (p for trend= 0.008) rising to a 2.7 fold (95% confidence interval: 1.2-6.4) increased risk in the highest exposure category. Aldicarb was associated with a significantly increased risk of colon cancer (p for trend=0.01), based on a small number of exposed cases, with the highest exposure category resulting in a 4.1 fold increased risk (95% confidence interval:1.3-12.8). Dichlorophenoxyacetic acid showed a significant inverse association with colon cancer but the association was not monotonic. The researchers recommended that their findings be treated with caution as the literature suggesting pesticides are related to colorectal cancer is limited. However, they concluded that there is a possibility of an association between exposure to certain pesticides and incidence of colorectal cancer among pesticide applicators and further research is necessary.

Lynch et al (2006) studied 57 311 licensed pesticide applicators in Iowa and North Carolina 1993-1997 (AHS cohort) and explored exposure to cyanazine and cancer incidence amongst

pesticide applicators. Pesiticide exposure information was collected by self-administered questionnaire on enrolment (1993-1997). Cancer incidence was followed through to January 2002. Over half of the applicators had greater than or equal to 6 years of exposure on enrolment and approximately 85% had begun using cyanazine before the 1990s. Poisson regression was used to calculate rate ratios (RR) and 95% confidence intervals (CIs) of multiple cancer sites among cyanazine-exposed applicators. Calculated p sub(trend)values, and all statistical tests were two-sided. Two exposure metrics were used: tertiles of life time days or exposure (LD) and intensity weighted (LD). No clear, consistent associations with cyanazine exposure and any cancer analysed in this study. The number of sites was small for certain cancers and this limited any conclusion with regard to ovarian, breast and some other cancers.

Another cohort study of 21 416 subjects (1 291 cases) in the period 1993-1997 in Iowa and North Carolina (AHS cohort) explored exposure to carbaryl (carbamate insecticide) amongst pesticide applicators and incidence of cancer. Pesticide exposure information was collected through a self administered questionnaire. Poisson regression used to calculate rate ratios (RR) and 95% confidence intervals (CIs) while controlling for potential confounders. Carbaryl was not associated with cancer risk overall. Relative to subjects who never used carbaryl, the melanoma risk was elevated with >175 life time exposure-days (RR = 4.11; 95% CI, 1.33-12.75; p trend = 0.07); >10 years of use (RR = 3.19; 95% CI, 1.28-7.92; p-trend = 0.04), or >or=10 dyas of use per year (RR =5.50; 95% CI, 2.19-13.84; p-trend <0.001) and risk remained after adjusting for sunlight exposure. Although not significant there appeared to be a trend of decreasing prostate cancer risk with increasing level of exposure. A small increase in NHL risk was observed using some, but not all, exposure measures. There were no associations observed with other examined cancer sites. The researchers concluded that the observed results were not hypothesised a-priori and limited study of their biological plausibility meant that these results should be treated with caution (Mahajan et al 2007).

A cohort study of 45 372 pesticide applicators in Iowa and North Carolina in the period 1993-1997 (AHS cohort) explored the association of phorate exposure with overall cancer incidence. Phorate use was not related to incidence in all cancers combined or to any individual cancer. However there were insufficient numbers to study non-Hodgkin lymphoma or leukaemia which have been linked to organophosphates in other studies. Prostate cancer was not significantly related to phorate use overall or among those without a family history, but the risk was increased among pesticide applicators with a family history of prostate cancer. The researchers concluded the observed statistical interaction suggests a gene-environment interaction between family history and phorate exposure in the incidence of prostate cancer, but it was suggested that other explanations are possible (Mahajan et al 2006).

In another study by Mahajan et al (2006b) of 45 372 pesticide applicators in Iowa and North Carolina between 1993 and 1997 (AHS cohort) explored exposure to fonofos and the risk of cancer. Pesticide exposure information was collected through a self administered questionnaire and poisson regression was used to calculate rate ratios (RR) and 95% confidence intervals (Cis) while controlling for potential confounders. Relative to the

unexposed, leukaemia risk was elevated in the highest category of life time and intensity-weighted exposure days, a measure that takes into account factors that might modify pesticide exposure. Risk of prostate cancer was not related to fonofos use overall, however among applicators with a family history of prostate cancer a significant dose-response trend for life time exposure-days was observed and intensity weighted results were similar. There were no observed associations with other examined cancer sites. The researchers concluded further research is needed to confirm findings with respect to leukaemia and to determine if genetic susceptibility modifies prostate cancer risk from pesticide exposure.

Nordby et al (2004) cohort study of 131 243 male Norwegian farmers, born 1925-1971, explored exposure to immunosuppressive substances (eg. Mycotoxins, pesticides) and lip cancer incidence. The male farmers were followed until 1999 for incidence of lip cancer. Farm production data from agricultural censuses and meteorological data on solar radiation and fungal forecasts served as exposure proxies. Adjusted rate ratios (RR) and 95% confidence intervals (CI) were estimated using Poisson regression. There were 108 lip cancer cases (rate 4.4 per 100 000 person-years) and the researchers found lip cancer cases to be moderately associated with there being horses on the farm; construction work employment; pesticide use; grain production and increasing levels of fungal forecasts. Researchers found moderate associations of lip cancer with grain production and fungal forecasts and argued that the negative association with pesticide could possibly be explained by exposure to immunosuppressive mycotoxins and that some of the associations observed could be explained by solar exposure.

Carreon et al (2005) conducted a case control study of 341 female glioma cases and compared with 528 controls, all of the participants were adults aged between 18 and 80 years and non-metropolitan residents of Iowa, Michigan, Minnesota, and Wisconsin. The study explored the relation between gliomas and farm pesticide exposure for women. Researchers made adjustments for age, age group, education, farm residence and found exposure to pesticides was not associated with an increased risk of intracranial gliomas in women. Researchers concluded that other farm related factors could be etiologic factors and noted that other studies have found an excess incidence amongst male farmers of brain cancers.

Another case control study of 862 cases of women with breast cancer and 790 controls without breast cancer in North Carolina in the period 1993-1996 investigated farming exposures and breast cancer. The exposure information was collected through personal interview. Unconditional logistic regression was used to calculate ORs and 95% confidence intervals. The results showed a possible increased risk of breast cancer among a subgroup of farming women who are more likely to be exposed to pesticides (Duell et al 2000).

An Australian case control study of occupational exposure to pesticides and the risk of non-Hodgkin’s lymphoma considered 694 cases with incident non-Hodgkin's lymphoma and compared these cases to 694 controls. Logistic regression was used to estimate the risks of non-Hodgkin's lymphoma associated with exposure to subgroups of pesticides after adjustment of age, sex, ethnic origin and residence. Approximately 10% of the cases and controls had incurred pesticide exposures. The study found that substantial exposure to any

pesticide was associated with a trebling of risk on non-Hodgkin's lymphoma. Subjects with substantial exposure to organochlorines, organophosphates and "other pesticides" (excluding herbicides) and herbicides other than phonoxy herbicides had similarly increased risks however these were statistically significant only for "other pesticides". The researchers concluded that these results were consistent with other research results (Fitschi et al 2005)

A population based case control study, conducted between 1 August 2001 and 1 October 2002 in Western Australia, of 606 men diagnosed with confirmed prostate cancer and 400 men who had undergone their first prostatectomy for benign prostatic hyperplasma (BPH) and compared with 471 male controls served as the basis of an assessment of the association of selected occupational exposures with risk of prostate cancer and with risk of benign prostatic hyperplasma (BPH). Logistic regressions were used for univariate and multivariate analyses to investigate two outcomes with occupational exposure to pesticides, fertilisers, metals, wood dust, oils, diesel exhaust and polyaromatic hydrocarbons (PAHs). The researchers concluded the results did not provide evidence that any of the occupational factors examined were risk factors for either prostate cancer or BPH (Fitschi et al 2007).

In New Zealand, t'Mannetje et al (2007) investigated 291 incident cases of non Hodgkin's lymphoma (25-70 years) identified in the New Zealand cancer registry in the period 2003-2004 and compared to 471 population controls. This nationwide case control study aimed to assess whether previously observed occupational associations with non-Hodgkin's lymphoma (NHL) in New Zealand persisted. Researchers employed a questionnaire to collect demographic information and a full occupational history from each participant. The relative risk for NHL associated with employment in particular occupations was calculated by unconditional logistic regression adjusting for age, sex, smoking, ethnicity and socioeconomic status. Estimates were then semi-Bayes adjusted to account for the large number of occupations and industries being considered. An elevated risk of NHL was observed for field crop and vegetable growers, and horticulture, and fruit growing; particularly for women. Sheep and dairy farming was not associated with any increased risk of NHL. Meat processors had an elevated risk, as did heavy truck drivers, workers employed in metal product manufacturing and cleaning. After semi-Bayes adjustment elevated risks in horticulture, fruit growing and metal product manufacturing and cleaning remained statistically significant and represented the most robust findings of this study.

A multicentre population based case control study of 710 male and female patients with malignant lymphoma aged 18-80 years and 710 controls in Germany served as a sample for researchers to identify occupations suspected of being associated with malignant lymphoma and to generate new hypotheses. Odds ratios (Ors) and 95% confidence intervals for major occupations and industries were calculated using logistic regression analysis and were adjusted for smoking (in pack years) and alcohol consumption. Patients with specific lymphoma sub-entities were additionally compared with the entire control group using unconditional logistic regression analysis. The authors observed an increased lymphoma risk among architects, maids, farmers, glass formers and construction workers. Follicular lymphoma showed highly significant risk increases for several occupational groups, including veterinary workers. Multiple myeloma showed a particularly pronounced risk

increase for farmers as well as for agricultural and animal husbandry workers (Mester et al 2006).

A nested case control study of prostate cancer of 222 newly diagnosed prostate cancer cases (1999) and 1110 age-matched controls in the USA investigated the relation between risk of prostate cancer and type of crops and commodities cultivated. The cohort for this study, were predominantly of Hispanic ethnicity and members of a labour union in California, the United Farm Workers of America. Electronic record linkage between the union register and the California Cancer Registry for the years 1988-1999 was created. Age matched controls were selected randomly from the remainder of the cancer cohort and it was concluded that Hispanic farm workers with relatively high exposure to organochlorine pesticides (lindane and heptachlor), organophosphate pesticides (dichlovos), fumigants (methyl bromide), or triazine herbicides (simazine) experienced elevated risk of prostate cancer compared to workers with lower levels of exposure (Mills 2003).

Ruder et al (2004) case control study investigated farm pesticide exposure and glioma risk and included 457 glioma cases which were compared to 648 population-based controls in Iowa, Michigan, Minnesota and Wisconsin. Multiple logistic regressions were used to control for farm residence, age, age group, education, and exposure to other pesticides. No positive association of farm pesticide exposure and glioma was found and the researchers concluded that other farm exposures may explain the excess brain cancer risk amongst farmers.

Samanic et al (2006) case control study investigated cancer incidence among pesticide applicators (n=41 969) exposed to dicamba and compared to 22,036 controls. Exposure information was collected through self-administered questionnaire completed between 1993 and 1997. Although associations between exposure and lung and colon cancer were observed, no clear evidence for an association between dicamba exposure and cancer risk was found.

Another case control study by Svec et al (2005) investigated whether occupational exposure to animals or the public could result in exposure to infectious agents which may play a role in the aetiology of lymphohaematopoietic (LH) cancers. The study included 72 589 cases of Non-Hodgkin’s lymphoma, 5 479 Hodgkin’s disease cases; 35 857 multiple myeloma cases; 68 698 cases of leukaemia and 912 615 controls in 24 States. Cases were selected on cause of death for: non-Hodgkin’s Lymphoma, Hodgkin's disease, multiple myeloma, and leukaemia and the controls were randomly selected from all remaining deaths. Frequency was matched for age, sex, race and geographic region. The results showed an increased risk of NHL, HD, multiple myeloma, and leukaemia was associated with occupations that involved animal exposure. Regional differences in risk implied that the risks may be associated with exposure to specific livestock or farming practices, however, researchers observed that these associations may be confounded by other farming related exposures, such as pesticides and that further exploration is necessary.

Lee et al (2004) case control study evaluated the risk of stomach and osesophageal adenocarcinomas and associations with farming and agricultural pesticide use. Research participants were men and women diagnosed with adenocarcinoma of the stomach (n=170);

or oesophageal adenocarcinomas (n=137) between 1988 and 1993 and were compared 502 non-farmer controls. Unconditional logical regression was used to calculate adjusted odds ratios (ORs) for farming and for use of individual and chemical classes of insecticides and herbicides, including pesticides classified as nitrosatable. There were no significant association found between specific agricultural pesticide exposures and the risk of stomach or oesophagael adenocarcinomas among these Nebraska farmers.

A case control study evaluated the risk of adult glioma associated with farming and agricultural pesticide use in Nebraska. Two hundred and fifty one men and women diagnosed with glioma in the period 1988-1993 were compared with 498 non-farmer controls. Unconditional logical regression was used to calculate adjusted odds ratios (ORs) for farming and for use of individual and chemical classes of insecticides and herbicides, including pesticides classified as nitrosatable (able to form N-nitroso compounds upon reaction with nitrite. Significant associations between some specific agricultural pesticide exposures for male farmers were found and ORs were significantly increased for the herbicides mertribuzin and paraquat, and for the insecticides bufencarb, cholorpyrifos and coumaphos (Lee et al 2005).

Provost et al (2007) conducted a case control study to investigate the relationship between exposure to pesticides and brain tumours in adults. Two hundred and twenty one incident cases of brain tumour were compared with four hundred and forty two controls in South West France. Histories of occupational and environmental exposures, medical and lifestyle information were collected from participants and a cumulative index was created. Separate analyses were performed for gliomas and meningiomas and the results suggested that a high level of occupational exposure to pesticides might be associated with an excess risk of brain tumours, especially gliomas.

Van Balen et al (2006) case control study estimated the risk of lymphoma among farmers in Spain. Patients diagnosed with Lymphoma in four hospitals in Spain in the period 1998-2002 were the research subjects. The results suggested that although farmers were not at an increased risk of lymphoma when compared to other occupations, farmers exposed to non-arsenic pesticides were found to have an increased risk of lymphoma with risk highest for those exposed for over nine years.

A meta-analysis of 22 studies conducted in the period 1966-2003 to determine if there was a possible relationship between cancer of the prostate and pesticide exposure revealed that there was substantial heterogeneity of rate ratios between the different studies. The major source of heterogeneity was identified as geographic location. There were increased meta-rate ratios from Europe and North America. The increased meta-rate ratio for prostate cancer in pesticide applicators provides additional evidence for a possible relationship between pesticide exposure and prostate cancer. Homogeneity between individual rate ratios, after they were regrouped geographically increased the consistency of the association. However, researchers concluded that overall there was insufficient exposure information from individual studies and that this absence precluded making any firm conclusions (Van Maele-Fabry 2004).

A case control study with 748 cases of Hodgkin's Lymphoma and 2236 population based controls in the United States sought to evaluate the relationship between the use of organophosphate pesticides and non-Hodgkin's Lymphoma (NHL) among white male farmers. Telephone or in person interviews were utilised to obtain data on the use of pesticides. Odds ratios were adjusted for age, state of residence, and respondent status, as well as other pesticide use where appropriate were estimated by logistic regression. Researchers found associations between the risk of NHL and several groupings and specific organophosphate pesticides, however larger risks from proxy respondents complicated the interpretation of results. However, associations between reported use of diazinon and NHL, particularly diffuse and small lymphocytic lymphoma found among subjects providing direct interviews could not easily be discounted (Waddell et al 2001).

Zheng et al (2001) case control study investigated the risk of non-Hodgkin lymphoma (NHL) from exposure to carbamate insecticide among farmers. Nine hundred and eighty five white male subjects were compared to 2895 control subjects in the Midwestern states of the United States. Unconditional logistic regression was used to estimate the association and to control for confounding. Compared with non-farmers, those farmers who had used carbamate insecticide had a 30% to 50% increased risk of non-Hodgkin's lymphoma. Among farmers using Sevin the risk of NHL was limited to those who personally handled the product, those who first used the product twenty or more years before their disease diagnosis. The results suggested an increased risk of NHL associated with carbamate pesticide use, particularly Sevin.

The relationship between organochlorine pesticides and the occurrence of pancreatic cancers was explored through an analysis of mortality data for the period 1989 to 1996 in the USA. Researchers employed a mortality odds ratio design to compare deaths from pancreatic cancer (1989-1996) with a random sample of non-pancreatic cancer deaths. Pesticide data and residential use data was employed and logistic regression analysis was used to estimate the effect of pesticide applications by ZIP code, with controlling for potential confounders. The study suggested increased pancreatic cancer mortality among long term residents in areas of high application rates of 1,3-d (an EPA-classified probably human carcinogen), captafol, pentacholoronitrobenzene (PCNB) and dieldrin (Clary 2003).

An analysis of industry and occupation coded mortality data in the period 1984-1993 in USA provided an evaluation of mortality patterns among crop and livestock farmers. Cause-specific proportionate mortality ratios (PMRs) were calculated using a National Institute for Occupational Safety and Health (NIOSH) program designed to calculate sex and race specific PMRs for industries and occupations in population-based data. Among white male livestock farmers there was significantly higher mortality from cancer of the pancreas, prostate and brain, non-Hodgkin's lymphoma, multiple lymphoma, acute and chronic lymphoid leukaemia, and Parkinson's disease. White male crop farmers showed significantly higher mortality risk of cancer of the lip, skin, multiple myeloma, and chronic lymphoid leukaemia. The disease trends suggest that livestock farmers might be exposed to more carcinogens or agricultural chemicals than crop farmers (Lee et al 2002).

t ‘Mannetje et al (2008) assessed whether farmers and meat-workers were at an increased risk of non-Hodgkin’s lymphoma (NHL). Drawing on data from a New Zealand cancer registry for the period 2003-2004 two hundred and ninety one incidence cases (aged between 25 and 75 years) of Non Hodgkin’s Lymphoma were identified and were compared to four hundred and seventy one population controls. Face to face interviews were conducted and demographic data and full occupational histories were collected. Relative risk of NHL associated with ever been employed in particular industries and occupations were calculated using logistic regression with adjusting for age, sex, smoking, ethnicity and socioeconomic status. Estimates were subsequently semi-Bayes adjusted to account for the large numbers of occupations and industries being considered. The study results confirmed that crop farmers and meat processing workers remain high risk occupations for NHL in New Zealand, and also identified several other occupations and industries of high NHL risk that merit further study.

An analysis of Cancer registry data in the period 1979-2000 in Saskatchewan, Canada explored the incidence rates of testicular cancer and the role of agricultural exposure for farmers and non-farmers. Logistic regression analyses with adjustment for relevant variables were conducted. Farmers were significantly more likely than non-farmers to be diagnosed at stage 2 or higher [1.76 (1.00-3.10)]. Based on this data the significant predictors of being diagnosed with stage 2 and higher are: presence on nonseminoma, for those less than or equal to 26 years of age, and farming as an occupation (McDuffie et al 2007).

Reynolds et al (2005) identified cases of invasive breast cancer in a cancer registry in the period 1988-1997 in California to ascertain whether Californian breast cancer rates were elevated in areas with recent high agricultural pesticide use. Researchers used California's pesticide use reporting data to select pesticides for analysis based on use volume, carcinogenic potential, and exposure potential. Census data was used to derive age and race specific population counts for the time period of interest and GIS was used to aggregate cases, population counts and pesticide use data for all block groups in the state. Rate ratios and 95% confidence intervals using Poisson Regression models, adjusting for age, race/ethnicity, neighbourhood socioeconomic status and urbanization were employed. The results from this study provide no evidence that these women living in areas of recent, high agricultural pesticide use experienced higher rates of breast cancer.

In another study, researchers evaluated whether the rates of lymphoproliferative malignancies among children were elevated in areas of intensive agricultural pesticide use in the state of California. Drawing on a cancer data base and cases recorded between 1988 and 1994 the study included all newly diagnosed, state-wide cases of childhood lymphoma and acute lymphoblastic leukaemia, among children less than 15 years of age. The generally null results from this study (which systematically examined the risk relationships for residential proximity to agricultural pesticide use) stand in contrast to existing epidemiological literature, which suggests elevated childhood cancer risks from reported household pesticide use. The researchers suggested that the differences may be due to different chemical agents, or different exposures: indoor and outdoor, or both and recommended further research on potential exposure for children to these agents (Reynolds et al 2005).

Researchers drew data from a Swedish cancer registry and records of male pesticide applicators in the period 1965-1976 were used to identify cancer rates amongst children born to pesticide applicators in this period. Cancer risk from date of birth until 1994 was explored in children born in and after 1958. Records of male pesticide applicators registered 1965-76 were linked to the Multi-generation Register. The records of their offspring were then linked to the Swedish Cancer Registry and the Cause of Death Register. None of the a-priori hypotheses of increased risk of tumours of the nervous system, kidney cancer, leukaemia, lymphoma, soft tissue sarcoma, and testicular cancer in children of male pesticide applicators could be confirmed (Rodvall et al 2003).

15.5 Respiratory Conditions

Occupational respiratory conditions amongst those engaged in agricultural production was the focus of a number of studies in the review period, there were 14 cohort studies, seven conducted in the USA and seven in Europe. In addition there were 11 cross sectional studies, with eight of these studies conducted in the USA, one in Europe, one in Australia and one in New Zealand. Eight prevalence surveys were also conducted, two in the USA and five in Europe, in addition there were two studies that drew on routine data, one in the United Kingdom and one in the USA.

15.6 Summary of studies

Cohort Studies

- In the United States a cohort study established in 1994 found pesticide use and other agricultural factors were linked to injuries, retinal degeneration and respiratory wheeze (Blair et al 2005b). Hoppin et al (2002) study explored associations between wheeze and pesticide use in the last year amongst pesticide applicators in Iowa and North Carolina. Of those pesticides suspected of contributing wheeze, paraquat, three organophosphates (parathion, malathion, and chlorpyrifos) and on thiocarbamate had elevated odds ratios (OR). The herbicides atgrazine and alachlor, but not 2,4,D were associated with wheeze. Researchers concluded the results suggest an independent role for specific pesticides in respiratory symptoms of farmers. The association of wheeze and animal production was explored by researchers and the results suggested subgroups (atopic, asthmatics and smokers) respond differently to exposure (Hoppin et al 2003). Hoppin et al's (2004) study examined exposure to diesel exhaust, solvents, welding fumes and other respiratory irritants and evaluated the odds of wheeze. The highest odds of wheeze for farm activities were from daily painting, an indication of daily solvent exposure. Researchers concluded that exposure to diesel and solvents can have adverse respiratory effects. Researchers investigated exposure to pesticides and respiratory outcomes including, wheeze, asthma, farmer's lung and chronic bronchitis. For farmers and non-farmers there was a strong association between organophosphates and wheeze. For farmers, the organophosphates: chlorpyfios, malathion and parathion were positively associated with wheeze. For commercial applicators the organophosphates, cholrpyrifos, dichlovos and phorate were positively associated with wheeze. In

another study the association of pesticides with wheeze in a population without other farming exposures was conducted. Eight of the 16 herbicides evaluated were associated with wheeze. The odds ratios for four organophosphate insecticides (terbufos, fonofos, cholrpyrifos and phorate) were elevated when modelled individually. In Iowa researchers investigated associations between farm and other environmental risks factors with four asthma outcomes. Researchers found independent associations between male sex, age, a personal history of allergies, family history of allergic disease, premature birth, early respiratory infection, high risk birth, and farm exposure to raising swine and adding antibiotics to feed (Merchant et al 2005).

A study of non-smoking farm women investigated agricultural risk factors for chronic-bronchitis. Applying manure and driving combines were independently associated with chronic bronchitis. Off farm job exposures associated with chronic bronchitis were organic dusts, asbestos, gasoline, and solvents. Five pesticides were also associated with chronic bronchitis (Valcin et al 2007). In Canada researchers investigated the respiratory health of male and female workers employed full-time in large-scale intensive swine operations in Saskatchewan. Researchers found that male and female workers were more likely to have chronic and unusual cough and chronic and unusual phlegm in comparison to male and female non-farming controls; and that the risk was greater for female workers (Senthilselvan et al 2007).

- In Europe, Chaudemanche et al (2003) explored the respiratory status of dairy farmers and that of non-farming controls. Researchers concluded dairy farming was associated with excess of chronic bronchitis, with a moderate degree of bronchial obstruction and a mild decrease in Sp02. Gainet et al (2007) documented the prevalence of respiratory conditions and farm exposures amongst dairy farmers and controls in Europe. The overall results demonstrated that dairy farming is associated with an increased risk of lung disorders and a decrease in blood oxygen saturation and suggests that respiratory function impairment is correlated with cumulated exposure to organic dusts.

In Denmark, a study investigated exposure to organic dust and airway obstruction amongst farmers working in confinement buildings. Working in confinement buildings causes an accelerated decline during a working life and will for some farmers result in the development of significant airway obstruction (Iversen 2000). Musken et al (2000) study of German farmers investigated the relation between exposure to house dust and storage mites and allergic airways disease. The most frequent sensitisations determined by skin tests were found for the three blomia species, E maynei and G domesticus. A considerable proportion of the farmers tested were sensitised to storage mites. Researchers concluded that B.tjibodas, G. domesticus, C. arcuatus and C. eruditus in particular should be included in an allergy diagnosis. In another study, researchers investigated exposure-response relationships for dust and ammonia and respiratory conditions among pig farmers in Europe. It was

found that exposure to dust and ammonia in pig farms contributes to chronic inflammation of the airways and such exposures should be reduced (Vogelzang et al 2000).

A study of thyme farmers in Poland investigated exposure to thyme dust and respiratory disorders. Thyme farmers engaged in threshing this herb were found to have elevated occupational risk and a high incidence of work-related symptoms and positive skin and preciptitin reactions to bacterial and fungal allergens associated with organic dust (Golec et al 2003). Researchers in the United Kingdom investigated occupational exposure to inhalable dust and ammonia for poultry stockmen working in barn systems. Current methods for assessing the combined effects of dust and ammonia indicated that 8 of the 12 barn stockmen were at risk compared with 1 of the 8 cage system stockmen (White 2002).

Cross sectional studies

- In Europe, a cross sectional survey of workers in summer and winter explored the association between airborne fungal spore concentration and respiratory conditions. Researchers concluded the presence of different spores in varying concentration in the working atmosphere may be responsible for the post shift decrement of PFT, allergic symptoms, high lgE level and respiratory impairments among the workers (Chattopadhyay et al 2007). In another study, researchers explored the association of allergic rhinitis with use of pesticides among grape farmers in Northern Crete. The researchers concluded occupational exposure to multiple agricultural chemicals could be related to allergic rhinitis in grape growers (Chatzi et al 2006). Danuser et al (2001) survey of Swiss farmers explored prevalence and risk factors of self-reported asthma, symptoms of chronic bronchitis, hay fever, and work related respiratory symptoms. The findings demonstrated that agricultural work in Switzerland is associated with elevated risk for reporting symptoms of chronic bronchitis and chronic phlegm compared with the general Swiss population. Working hours spent in animal confinements was identified as the exposure-response relationship. Research with Norwegian farmers explored the prevalence of asthma in farmers with different exposure levels to microbial agents and irritant gases. Researchers concluded exposure to endotoxins and fungal spores appears to have a protective effect on atopic asthma but may induce non-atopic asthma in farmers (Eduard et al 2001). A study that explored whether farming practice amongst crop farmers was a risk factor for the respiratory symptoms of obstructive lung disease. The researchers concluded that flower and oil plant production is associated with an increased risk of respiratory symptoms in European crop farmers (Monso et al 2000). A survey of animal farmers in Europe investigated airway symptoms in different types of animal farmers (cattle, pigs, poultry and sheep) and compared with prevalence in the general population. Prevalence of wheezing, shortness of breath, asthma and nasal allergies were significantly lower among all farmers in the 20-44 year age group than among the general population. The prevalence of bringing up phlegm

amongst farmers was more prevalent than among the general population. Researchers concluded that farming could be negatively related to allergic diseases (Radon et al 2001). Talini et al's (2003) study explored prevalence of respiratory symptoms in agricultural workers and occupational risk factors. The researchers concluded that symptoms of chronic bronchitis were frequent in this population of farmers in Middle Italy and that tasks in the cowshed are a specific occupational risk factor in respiratory disorders.

- A cross sectional study in California and Europe explored the relation between respiratory symptoms and farm characteristics and sought to identify risk factors. Respiratory symptoms were found to be associated with poultry and rabbit farming, flower growing and the cultivation of grain and oil plants. Working in Europe was a statistically significant risk factor for chronic bronchitis and toxic pneumonitis. Chronic bronchitis and toxic pneumonitis are highly prevalent in European farmers and are mainly attributable to indoor work (Monso 2003).
- A cross sectional study in the United States explored the relationship between agricultural environments and olfactory dysfunction. No relationship was established, however, certain groups of farmers were identified with inflammatory type reactions and appeared to be more susceptible to olfactory loss (Snyder 2003).
- In Australia researchers investigated whether having lived on a farm as a child in Australia is associated with a lower risk of allergic diseases. Researchers concluded that having lived on a farm in Australia can confer protection against atopy in children. They recommended further research exploring the possible mechanisms associated with farm animals or to establish whether this protective effect is explained by other related exposures (Downs et al 2001).
- In New Zealand a cross sectional study of farm children explored whether there was a reduction in allergy amongst New Zealand farm children with early life farming exposures. Despite finding a protective effect of early-life animal exposures, researchers found a greater prevalence of allergic disease on farms. Researchers noted that the sample size for this study was small and there was a limited ability to generalise, nonetheless the study did include had a good cross section of animal farmers and was climatically representative of most of New Zealand (Wikens et al 2002).

Prevalence Surveys:

- In the United Kingdom researchers investigated the burden of obstructive lung disease and occupational exposure. Farming was found to be significantly associated with airways obstruction even after adjustments were made for age, gender and smoking. The risk of non-reversable airways obstruction attributable to farming was seven percent (7.7%) (Lamprecht et al 2007). Melbostad's (2001) research investigated exposure to organic dust and work related respiratory and other symptoms. Work related symptoms were found to be common in farmers and were associated with exposure to total dust, fungal spores and endotoxins. Radon et al (2000) study of swine producers evaluated the characteristics of pig

houses and associations with the development of respiratory morbidity. Among symptomatic pig farmers, those with higher numbers of pigs and longer duration of employment were at highest risk for developing functional impairment. The relation between spirometric findings, farming characteristics and exposure to organic dust amongst poultry and pig farmers in Europe was the focus of a study that found ventilation of the animal house and temperature might influence respiratory morbidity in farmers (Radon et al 2001). In another study, Radon et al (2007) explored environmental exposure to concentrated animal feeding operations and respiratory health. Researchers concluded that confined animal feeding operations may contribute to the burden of respiratory disease among their neighbours. Researchers explored the prevalence of respiratory symptoms amongst sheep breeders and potential work related risk factors in Germany and concluded that sheep breeders might be at risk of the development of respiratory symptoms and that these symptoms may be associated with work intensity and chemical exposure during work (Radon et al 2003). A study in the Netherlands focused on the effects of organic farming on respiratory health. The research produced evidence that a farm based childhood in combination with current livestock farming protects against allergic disorders (Smit et al 2007).

- In the United States a study investigated the relation between dust exposure in agriculture and respiratory symptoms. Occupational dust exposure among Californian farmers, only one third of whom tended animals, was independently associated with chronic respiratory symptoms (Schenker et al 2005). Sprince et al (2000) study examined the risk of airways disease resulting from exposures including organic agents and chemicals on the farm. The results demonstrated an association between insecticide application to livestock and symptoms of airways disease. This was a new finding and researchers recommended further research into specific airway responses and exposures associated with this practice. Associations between respiratory symptoms and conventional vertical silos in farm buildings were also established.

Analyses of Routine Data:

- An analysis of national surveillance data in the United Kingdom found that reported incidence of new cases of acute respiratory illness caused by work remains substantial (MacDonald et al 2005).
- An analysis of national data sought to estimate the prevalence of work related wheezing in the United States amongst workers 20 years and over. The main industries identified at risk of work related asthma and wheeze were the entertainment industry, agriculture, forestry and fishing, construction, electrical machinery, repair services and lodging places (Arif et al 2002).

15.8 The studies:

Blair et al (2005b) undertook a cohort study of 85 658 pesticide applicators and their spouses in Iowa and North Carolina in the period 1993-1997 explored agricultural exposure and risk

factors for disease linked to pesticides. Pesticide use and other agricultural factors were linked to: injuries, retinal degeneration, and respiratory wheeze.

Another cohort study explored the respiratory status of dairy farmers. The cohort of 215 dairy farmers was established in 1994 and was compared to 110 non farming controls. The research protocol comprised a medical and occupational questionnaire, spirometric tests at both evaluations, allergological tests at T1, and a non-invasive measure of blood oxygen saturation (SpO2) at T2. Researchers concluded dairy farming is associated with excess of chronic bronchitis, with a moderate degree of bronchial obstruction and a mild decrease in SpO2 (Chaudemanche et al 2003).

Gainet et al (2007) cohort study documented the prevalence of respiratory conditions and farm exposures for 157 dairy farmers and compared with 159 non farming controls in Europe. The cohort was established in 1986 and re-evaluated in 1998. The study protocol comprised a medical and occupational questionnaire, spirometric tests at both evaluations and a non-invasive measure of blood oxygen saturation with pulse osimetry. In 1998, the prevalence of chronic bronchitis was higher in dairy farmers. The overall results demonstrated that dairy farming is associated with an increased risk of lung disorders and a decrease in blood oxygen saturation and suggested that respiratory function impairment is correlated with cumulated exposure to organic dusts.

Another cohort study of 20 468 applicators in Iowa and North Carolina aged 16-88 years explored associations between wheeze and pesticide use in the last year. Self administered questionnaires addressed 40 currently used pesticides and pesticide application practices. Nineteen percent reported wheeze in the last year. Logistic regression models controlling for age, state, smoking, history of asthma or atopy, were used to evaluate associations between individual pesticides and wheeze and of those pesticides suspected of contributing to wheeze, paraquat, three organophosphates (parathion, malathion, and chlorpyrifos) and one thiocarbamate (S-ethyl-dipropylthiocarbamate (EPTC) had elevated odds ratios (OR). Parathion had the highest OR (1.5, 95% confidence interval [CI] 1.0, 2.2). Chlorpyrifos, EPTC, paraquat, and parathion demonstrated significant dose-response trends. The herbicides, atrazine and alachlor, but not 2,4-D, were associated with wheeze. Atrazine had a significant dose-response trend with participants applying atrazine more than 20 days/year having an OR of 1.5 (95% CI 1.2, 1.9). Inclusion of crops and animals into these models did not significantly alter the observed OR. While these associations are small, researchers concluded they suggest an independent role for specific pesticides in respiratory symptoms of farmers (Hoppin et al 2002).

Another cohort study by Hoppin et al (2003) of the same pesticide applicators 20 468 explored the association of wheeze with animal production. Exposure to animals, their feeds, and by-products was documented in order to understand how they contribute to respiratory symptoms. Researchers aimed to assess whether the impact varied among the subgroups: atopics, asthmatics and smokers. Individuals raising animals requiring direct contact had the highest odd ratios (OR) for wheeze (OR (dairy)=1.26; OR(eggs) = 1.70. A significant dose response was observed for both the number of poultry and the number of livestock on the

farm. Those who performed veterinary procedures had an OR of 1.51. Odds of wheeze associated with poultry production was greater among atopic than non-atopic individuals. Milking cows daily increased the odds of wheeze for all individuals with the largest association being for those who were atopic asthmatic individuals. The impact of poultry, diary, and egg production varied among smoking groups. Past smokers had the highest odds ratios, followed by never smokers, and then current smokers. The OR (eggs) was 2.88 among past smokers but only 1.46 for never smokers. Researchers suggested the OR (eggs) for current smokers of 0.80 might reflect self selection of exposure among smokers. The results were consistent with animal production and respiratory symptoms and suggested the subgroups (atopic, asthmatics and smokers) respond differently to exposure.

A further study by Hoppin et al (2004) with the same cohort examined exposure to diesel exhaust, solvents, welding fumes and other respiratory irritants and evaluated the odds of wheeze associated with non-pesticide occupational exposures. Self administered questionnaires were employed to document exposures. Logistic regression models controlling for age, state, smoking and history of asthma or atopy were employed to evaluate the odds of wheeze over the last 12 months. Driving diesel tractors was associated with elevated odds of wheeze (OR = 1.31; 95% confidence interval - 1.13, 1.52); the odds ratio for driving gasoline tractors was 1.11 (95% confidence interval =1.02, 1.21). A duration-response relationship was observed for driving diesel tractors but not for driving gasoline tractors. Activities involving exposure to solvents (painting and cleaning) were associated with increased odds of wheeze in a duration-dependent way. The highest odds of wheeze for farm activities were from daily painting, an indication of daily solvent exposure. These results add to a growing body of evidence that exposure to diesel and solvents can have adverse respiratory effects.

A cohort study of 89 000 licensed pesticide applicators and their spouses in Iowa and North Carolina investigated exposure to pesticides and respiratory outcomes including: wheeze, adult asthma, farmers' lung, and chronic bronchitis. Self administered questionnaires documented exposure and use of 40 individual pesticides and 19% of farmers and 22% of commercial pesticide applicators reported wheeze in the previous year. Using logistic regression models adjusted for age, state, smoking status, and body mass index the researchers evaluated the association of 40 individual pesticides with wheeze within these two groups, separately. For both groups there was strong evidence of an association between organophophates and wheeze. For farmers: the organophosphates, chlorpyfios, malathion, and parathion were positively associated with wheeze. For the commercial applicators: the organophosphates, chlorpyrifos, dichlorvos, and phorate were positively associated with wheeze. Chlorpyrifos was strongly associated with wheeze in a dose-dependent manner in both groups; use of chlorpyrifos for at least 20 days per year had an odds ratio of 1.48(95% confidence interval (CI) = 1.00-2.19) for farmers and 1.96 (95% CI=1.05-3.66) for commercial applicators (Hoppin et al 2006).

Another cohort study of 2 255 Iowa pesticide applicators investigated the association of pesticides with wheeze in a population without other farming exposures. Controlling for age, smoking status, asthma and atopy history and body mass, index odds ratios were calculated

for the relationship between wheeze and 36 individual pesticides which participants had used during the year before enrolment (1993-1997). Eight of the 16 herbicides were associated with wheeze in single-agent models; however the risk was almost exclusively associated with the herbicide chorimuron-ethyl (odds ratio (OR) =1.62, 95% confidence interval (CI): 1.25, 2.10). Inclusion of chlorimuron-ethyl in models for other herbicides virtually eliminated the associations. The odds ratios for four organophosphate insecticides (terbufos, fonofos, chlorpyrifos and phorate) were elevated when modelled individually and remained elevated though attenuated a little, when chlorimuron-ethyl was included. The association of dicholorvos was not attenuated by cholorimuron-ethyl (OR =2.48, 95%CI: 1.08, 5.66). Dose response trends were observed for chlorimuron-ethyl, chlorpyrifos, and phorate, the strongest OR was for applying chlorpyrifos on more than 40 days per year (OR=2.48, 95% CI: 1.24, 4.65 (Hoppin et al 2006).

A seven year follow-up of a cohort of 181 Danish farmers investigated exposure to organic dust and airway obstruction amongst farmers working in confinement buildings. Researchers found that working in swine confinement units causes an accelerated decline in forced expiratory volume in one second but not in forced vital capacity. The mean decline was approximately 0.5L during a working life and researchers concluded that some farmers will develop clinically significant airway obstruction due to work in swine confinement units (Iversen 2000).

Researchers investigated associations between farm and other environmental risk factors with four asthma outcomes amongst children in Iowa. The four outcomes included: 1) doctor diagnosed asthma; 2) doctor diagnosed asthma/medication for wheeze, 3) current wheeze, and 4) cough with exercise. Multivariable models of the four health outcomes found independent associations between male sex, age, a personal history of allergies, family history of allergic disease, premature birth, early respiratory infection, high-risk birth, and farm exposure to raising swine and adding antibiotics to feed (Merchant et al 2005).

A cohort study of 86 German farmers with rhinitis and/or asthma investigated the relation between exposure to house dust and storage mites and allergic airways disease. Data was collected by skin prick testing and/or enzyme allergosorbent test (EAST) with the following mites: Blomia tjibodas, Blomia tropicalis, Blomia kulaginin, Glycyphasgus domesticus, Thyreophasgus entomophagus, Euroglyphus maynei, Chortoglyphus arcutas, Dermatophagoides pteronyssinus, Derma tophagoides farinae, Acarus siro, Lepidoglyphus destructor, Tyrophagus putrescentiae, Acarus farris and Cheyletus eruditus. The most frequent sensitisations determined by skin tests were found for the three blomia species, E maynei and G domesticus. A considerable proportion of German farmers tested were sensitised to storage mites. It was concluded that B tjibodas, G. domesticus, C. arcuatus and C. eruditus in particular should be included in an allergy diagnosis and that further research should explore the clinical relevance of the sensitisations and possible cross-reactivity between mite species (Musken et al 2000)

An investigation into agricultural risk factors for chronic bronchitis amongst a cohort of non-smoking farm women in Iowa and North Carolina found applying manure and driving combines were independently associated with chronic bronchitis. Off farm job exposures associated with chronic bronchitis were organic dusts, asbestos, gasoline, and solvents. Five pesticides were also associated with chronic bronchitis after mulitvariate adjustment and sensitivity analyses: dicholorvos; cyanazine; paraquat; and methyl bromide and pesticides, grain and dust exposures were associated with chronic bronchitis among non-smoking farm women (Valcin et al 2007).

Another study investigated exposure-response relationships for dust and ammonia and respiratory conditions among a cohort of 171 pig farmers in Europe. Bronchial responsiveness was assessed by a histamine provocation test. Long term average exposure to inhalable dust and endotoxin was determined by personal monitoring in summer and winter. Additionally farm characteristics and activities were also recorded. Researchers concluded that exposure to dust and ammonia in pig farms contributes to chronic inflammation of the airways and should be reduced (Vogelzang et al 2000).

A case control study in eastern Poland investigated exposure to thyme dust and respiratory disorders amongst 47 Thyme farmers and 63 urban dwellers. Medical examinations were performed on the farmers and non-farmers. The examinations included an interview concerning the occurrence of respiratory disorders, work-related symptoms, physical examination, lung function tests and skin prick tests with four microbial allergens and agar-gel precipitation tests with 12 antigens. It was found that thyme farmers engaged in threshing this herb have elevated occupational risk, a high incidence of work-related symptoms and common occurrence of positive skin and preciptitin reactions to bacterial and fungal allergens associated with organic dust (Golec et al 2003).

Senthilselvan et al (2007) study investigated the respiratory health of male and female workers employed full time in large-scale intensive swine operations in Saskatchewan. Results were controlled for age and smoking and the researchers found that male and female workers were more likely to have chronic and unusual cough, and chronic and unusual phlegm in comparison to male and female non-farming control subjects and that the risk of these symptoms was greater in female workers. There were no observed increased risks for asthma or asthma like symptoms among female workers. Male workers had increased risk of shortness of breath in comparison with non-farm control males. The researchers concluded that swine workers had increased risk of chronic and usual bronchitis-like symptoms and female workers appeared to be at greater risk of these symptoms.

Whyte (2002) case control study of 12 stockmen working in barn systems in the United Kingdom investigated occupational exposure to inhalable dust and ammonia for poultry stockmen. Exposures were measured and compared with established limits for occupational exposure. The individual values of dust exposure for 4 of the 12 stockmen exceeded the occupational exposure standard (OES) of 10.0mg/m3 for inhalable dust, but OES was not exceeded for all stockmen. The mean ammonia exposure experienced by poultry stockmen working in barn systems was 14ppm (11ppm, time-weighted average), for the complete

working day. None of the individual values of ammonia exposures for both barn and cage system stockmen exceeded the OESs of 25ppm, although the short term limit of 35ppm for 15 minutes was exceeded on a number of occasions. Current methods for assessing the combined effects of dust and ammonia indicated that 8 of the 12 barn stockmen were at risk compared with 1 of the 8 cage system stockmen.

A cross-sectional survey of 316 workers, in summer (n=136) and in winter (n=180) was conducted to explore association between airbone fungal spore concentration and respiratory conditions. Air sampling was done in summer and in the winter to measure airborne fungal spore concentration inside the godowns using Rotorod sampler. UK.Aspergilla, Alternaria, Drechslera, Epicoccum, Nigrospora, Periconia were all common and found in higher concentrations in the winter. Respiratory functional status was assessed among workers in summer and winter and restrictive, obstructive and combined types of respiratory impairments were noticed among the workers. The workers were of similar age, height and weight. The researchers concluded that the presence of different spores in varying concentration in the working atmosphere may be responsible for the post shift decrement of PFT, allergic symptoms, and high lgE level and respiratory impairments among the workers (Chattopadhyay et al 2007).

A cross-sectional survey of 120 grape farmers and 100 controls in Northern Crete explored the association of allergic rhinitis with use of pesticides among grape farmers. The research protocol consisted of a questionnaire, skin prick tests for 16 common allergens, measurement of specific IgE antibodies against 8 allergens, and spirometry before and after bronchodilatation. The researchers concluded that occupational exposure to multiple agricultural chemicals could be related to allergic rhinitis in grape farmers (Chatzi Let al 2006).

A cross sectional study in the United States explored the relationship between agricultural environments and olfactory dysfunction. Farming generally was not found to be associated with olfactory loss, however, certain groups of farmers were identified with inflammatory type reactions and appeared to be more susceptible to olfactory loss (Snyder 2003).

In Australia et al (2001) conducted a cross-sectional survey of 1500 children, aged 2-7 years, from two rural towns (Wagga Wagga and Moree in a crop farming region) and investigated whether having lived on a farm as a child in Australia was associated with a lower risk of allergic diseases. The research protocol involved parental responses to a questionnaire and skin prick tests for atopy from the children. Researchers concluded that having lived on a farm in Australia can confer protection against atopy in children and that further studies are needed to identify possible mechanisms associated with farm animals or to establish whether this protective effect is explained by other related exposures.

Danuser et al (2001) cross-sectional survey of 1 542 Swiss farmers explored prevalence and risk factors of self-reported asthma, symptoms of chronic bronchitis, hay fever, and work related respiratory symptoms (known as the Swiss population study, SAPALDIA-Study). Farmers were divided into seven groups according to the time farmers spent in different

animal confinement buildings. Multivariate analysis was performed with the methods of binary and mulitvariate logistic regression adjusted for age and smoking habits. This study demonstrated that agricultural work in Switzerland is associated with an elevated risk for reporting symptoms of chronic bronchitis and chronic phlegm compared with the general Swiss population.

In another cross-sectional survey of 2169 farmers in Norway the prevalence of asthma in farmers with different exposure levels to microbial agents and irritant gases was explored. Atopy was defined as a positive response to multiple radioallergosorbent tests (RAST) with a panel of 10 common respiratory allergens, and asthma was ascertained by a questionnaire using a stratified sample (n=2169) of a farming population in south-east Norway. Researchers concluded exposure to endotoxins and fungal spores appeared to have a protective effect on atopic asthma but may possibly induce non-atopic asthma in farmers (Eduard et al 2004).

In a study that explored whether farming practice amongst crop farmers was as a risk factor for the respiratory symptoms of obstructive lung disease, researchers surveyed 4 793 crop farmers in Europe. The researchers concluded that flower and oil plant production is associated with an increased risk of respiratory symptoms in European crop farmers (Monso et al 2000).

Another study by Monso et al (2004) involved a cross-sectional survey of 105 European farmers and sought to determine the characteristics and risk factors for chronic obstructive pulmonary disease (COPD) in never-smoking European farmers working inside animal confinement buildings. The study assessed lung function and air contaminants and dose-response relationships were assessed using logistic regression models. Researchers concluded that chronic obstructive pulmonary disease (COPD) in never smoking animal farmers working inside confinement buildings is related to indoor dust exposure and may become severe.

A cross-sectional survey of 6 156 animal farmers in Europe investigated airway symptoms in different types of animal farmers (cattle, pigs, poultry and sheep) and compared to prevalence in the general population. Animal farmers in Denmark, Germany, Switzerland and Spain completed a questionnaire on respiratory symptoms and farming characteristics from 1995-1997. This was compared with the results of the European Community Respiratory Health Survey (ECRHS) obtained in the same regions. Prevalence of wheezing, shortness of breath, asthma and nasal allergies were significantly lower among all farmers in the 20-44 yrs age group than among the general population. Nasal allergies were associated with the development of chronic phlegm. The prevalence of bringing up phlegm in winter among farmers was significantly higher than in the general population. The study supports the hypothesis that farming could be negatively related to allergic diseases (Radon et al 2001)

Talini et al (2003) conducted a cross-sectional survey of 461 agricultural workers in Tuscany and explored the prevalence of respiratory symptoms in agricultural workers and occupational risk factors. Study participants included workers from two different areas in Tuscany. Participants responded to a respiratory questionnaire, pulmonary function test and

skin prick tests. Occupational risk factors were assessed in response to questions related to 11 specific tasks, most of them related to work in cow-sheds. The researchers concluded that symptoms of chronic bronchitis were frequent in this population of farmers in Middle Italy and that tasks in the cow-shed are a specific occupational risk factor in respiratory disorders.

A cross-sectional study of 1 839 Californian farmers and 7,188 European farmers from 1993-1997 explored the relation between respiratory symptoms and farm characteristics and sought to identify risk factors. Respiratory symptoms and farming characteristics were assessed by questionnaire and risk factors associated with symptoms using logistic regression. Respiratory symptoms were associated with poultry and rabbit farming, flower growing and the cultivation of grain and oil plants. Working in Europe was a statistically significant risk factor for chronic bronchitis and toxic pneumonitis. The researchers concluded that chronic bronchitis was related to toxic pneumonitis, work inside confinement buildings and greenhouses and that chronic bronchitis and toxic pneumonitis are highly prevalent in European farmers and that this is mainly attributable to indoor work (Monso 2003)

Wikens et al (2002) cross sectional survey of 293 farm children in New Zealand sought to determine if there was a reduction in allergy amongst New Zealand farm children, as had been found in international research. The children surveyed were aged between 7-10 years and skin prick tests (SPT) were conducted on the children for eight common allergens. Parents completed a questionnaire that addressed allergic and infectious diseases, place of residence, exposure to animals, and diet and dust levels from their living room floor. It was found that current farm abode increased the risk of having symptoms of allergy, but not skin prick test (SPT) positively. Despite finding a protective effect of early-life animal exposures, researchers found a greater prevalence of allergic disease on farms. The researchers also noted that while they had limited ability to generalise the study findings because of the small sample size, the farmers in this study represented a good cross section of animal farmers and the region in which the study was conducted was climatically representative of most of New Zealand.

A prevalence survey with 2 200 adults investigated the burden of obstructive lung disease and occupational exposure in the United Kingdom. The study sample was a gender stratified, population-based sample of 2,200 adults aged 40 years and over. Pre- and post bronchodilator spirometry, information on smoking, occupation, and reported respiratory disease were recorded. Non-reversible airways obstruction was defined as a post-bronchodilator forced expiratory volume (FEV (1)/forced vital capacity (FVC) <0.70. Farming was defined as ever having worked in farming for 3 months or longer and twenty two percent (22.9%) of respondents reported farming. The prevalence of non-reversible airways obstruction amongst these participants was 30.2% and farming was significantly associated with airways obstruction even after adjustments were made for age, gender, and smoking. The risk for non-reversible airways obstruction attributable to farming was 7.7% (Lamprecht et al 2007).

In another prevalence survey, researchers investigated exposure to organic dust and work-related respiratory conditions and other symptoms amongst 8 482 farmers and their spouses. Task related respiratory and eye symptoms were recorded by questionnaire. Personal

exposure to total dust, fungal spores, bacteria, endotoxins, and ammonia during 12 different tasks was measured in a random sample of 127 farms (288 measurements). It was concluded that work related symptoms are common in farmers and are associated with exposure to total dust, fungal spores, and endotoxins (Melbostad 2001).

Radon et al (2000) prevalence study of 100 swine producers evaluated the characteristics of pig houses and associations with the development of respiratory morbidity. A questionnaire collected information on farm characteristics and lung function was assessed immediately before and after feeding the pigs. Exposure to dust and endotoxin was determined by personal sampling. Among symptomatic pig farmers, the study showed that those with higher numbers of pigs and longer duration of employment are at highest risk for developing functional impairment.

A prevalence study of 36 poultry farmers and 40 pig farmers explored the relation between spirometric findings and farming characteristics and exposure to organic dust. Farmers were chosen randomly and were assessed over a working day. Researchers concluded that ventilation of the animal house and temperature might influence respiratory morbidity in farmers (Radon et al 2001).

Radon et al (2003) prevalence study of 325 sheep breeders in Germany explored the prevalence of respiratory symptoms in sheep breeders and potential work related risk factors. Participants responded to a mailed questionnaire sent to all sheep breeders in two regions in Germany, prevalence results were then compared to the results of the European Farmers Study. Researchers concluded that sheep breeders might be at risk of the development of respiratory symptoms and that these symptoms may be associated with work intensity and chemical exposure during work.

In another prevalence survey by Radon et al (2007) of 6 937 adults aged 18-45 years in Germany, environmental exposure to concentrated animal feeding operations and respiratory health was explored. The sample was drawn from four rural towns in Germany with a high density of confined animal feeding operations. Researchers concluded that confined animal feeding operations may contribute to the burden of respiratory disease among their neighbours.

A prevalence survey of 1 947 Californian farmers investigated the relationship between dust exposure in agriculture and respiratory symptoms. The survey collected information on respiratory symptoms and occupational and personal exposures. Logistic regression models were used to assess associations between dust and respiratory symptoms. The study found that occupational dust exposure among Californian farmers, only one third of whom tended animals, was independently associated with chronic respiratory symptoms (Schenker et al 2005).

Sprince et al (2000) prevalence survey of 385 farmers examined risk of airways disease resulting from exposures including organic agents and chemicals on the farm. A stratified two stage cluster sample provided a representative farmer sample from the state. Participants responded to a questionnaire recording respiratory symptoms, smoking, and exposure

information. Logistic regression analysis was conducted and adjusted for age and smoking. The results of this study demonstrated an association between insecticide application to livestock and symptoms of airways disease. This is a new finding that could lead to further study of specific airway responses and exposures associated with this practice. Associations between respiratory symptoms and conventional vertical silos in farm buildings were also established.

A prevalence survey of 1798 farmers in The Netherlands studied the effects of organic farming on respiratory health. Researchers compared hay fever and asthma like symptoms in organic and conventional farmers to assess associations between current and childhood farm exposures and respiratory health effects. The research produced evidence that a farm childhood in combination with current livestock farming protects against allergic disorders. This effect was found for both organic and conventional farmers (Smit et al 2007).

McDonald et al (2005) drew on national surveillance data in the United Kingdom in the period 1992-2001 to summarise incidence rates and epidemiological characteristics of new cases of work related respiratory disease. Particular attention was paid to occupation, industry, causal agents for asthma, inhalation accidents and allergic alveiolitis. Cases reported between 1992 and 2001 were analysed by age, sex, cause, occupation and industry with incidence rates calculated against appropriate denominators. The researchers concluded the reported incidence of new cases of acute respiratory illness caused by work remains substantial.

An analysis of a national health and nutrition survey from the period 1988-1994 in the USA was used to estimate the prevalence of work related wheezing in United States workers aged 20 and over; to identify high risk industries, and to determine the population attributable risk of work related asthma and work related wheezing. Work related asthma was defined as an affirmative response to questions on self reported physician diagnosed asthma and work related symptoms of rhinitis, conjunctivitis, and asthma. Work related wheezing was defined as an affirmative response to questions on self reported wheezing or whistling in the chest in the previous 12 months and work related symptoms of rhinitis, conjunctivitis, and asthma. The main industries identified at risk of work related asthma and wheeze were the entertainment industry, agriculture, forestry and fishing, construction, electrical machinery, repair services and lodging places. The population attributable risk for work related asthma was 36.5% and work related wheezing was 28.5% (Arif et al 2002).

15.9 Fertility

One cross sectional study was found which explored the relation between solvent exposure and sub-fertility amongst couples where one partner was a pesticide applicator.

16.0 Summary of study

- A cross sectional study in the United States explored the relation between solvent exposure and sub-fertility among families of male licensed pesticide applicators. Researchers concluded that solvents may impair fertility of either gender, though the evidence for female effects were stronger than for male effects (Sallmen et al 2006).

16.1 The study

Sallmen et al (2006) cross-sectional survey of 2112 couples, where the wife was less than forty years of age, between 1993 and 1997 explored solvent exposure and sub-fertility among families of male licensed pesticide applicators . Twenty eight percent of couples were defined as sub-fertile. Adjusted sub-fertility odds ratios (OR) for exposure to solvents were calculated with logistic regression and the researchers concluded that solvents may impair fertility of either gender, though the evidence for female effects is stronger than for male effects.

16.2 Mortality

Three cohort studies were found, two conducted in the United States and one in New Zealand. All three examined exposure to pesticides/herbicides and mortality.

16.3 Summary of studies

Cohort Studies

- In the United States mortality rates of pesticide applicators and their spouses were assessed. Researchers concluded when compared to the general population in two states, the cohort experienced very low mortality. They concluded that several factors might have contributed to this low mortality rate, including healthy worker effect typically seen in cohorts of working populations and where this may decline in future. It was also suggested that the short follow- up interval and healthier lifestyle manifest in low cigarette use in combination with an occupation demanding high levels of physical activity may also have contributed to the low mortality rate (Blair et al 2005). A study of the use of agricultural chlorpyrifos exposure and mortality amongst pesticide applicators in the Iowa and North Carolina found that for most cases there was no evidence of an exposure response relationship. However, the relative risk of suicide and non-motor vehicle accidents increased two fold in the highest category of chlorpyrifos exposure days. Researchers concluded there may be a link between use of chlorpyrifos and depression and other neurobehavioural symptoms (Lee et al 2007).
- In New Zealand a cohort study explored the relation between exposure to dioxin and phenoxy herbicides and mortality for phenoxy herbicide producers and sprayers. Associations were found to be stronger for those exposed to multiple agents including dioxin during production. Overall, cancer mortality was not increased for producers and sprayers who were mainly handling final technical products, although they were likely to have been exposed to TCDD levels far higher than those currently in the general population (t'Mannetje et al 2005).

16.4 The Studies

Blair et al (2005) cohort study of 52 393 applicators and 32 345 spouses of farmers in Iowa and North Carolina documented mortality rates for pesticide applicators and their spouses. At enrolment applicators completed an enrolment questionnaire. Mortality assessment from enrolment (1994-1997) through to 2000 provided an average follow-up of about 5.3 years, 447 154 person years, and revealed 2055 deaths. When compared to the general population in the two states, the cohort experienced a very low mortality rate. Researchers concluded that

several factors might have contributed to this low mortality rate, including health worker effect typically seen in cohorts of working populations and where this may decline in the future; a short follow-up interval; healthier lifestyle manifest in low cigarette use and an occupation that has traditionally demanded high levels of physical activity.

Lee et al (2007) cohort study of 55 071 pesticide applicators (AHS study) in Iowa and North Carolina evaluated whether agricultural chlorpyrifos exposure was associated with mortality. Information was obtained through self administered questionnaires completed at the time of enrolment (1993-1997). Life time chlorpyrifos use was divided into tertiles and Poisson regression analysis was used to evaluate the exposure-response relationships between chlorpyrifos use and causes of death after adjustment for potential confounders. A total of 1 851 deaths (588 among chlopyrifos users) were observed during the study period, 1993-2001. The relative risk (RR) of death from all causes combined among applicators exposed to chlorpyrifos was slightly lower than that for non-exposed applicators. For most causes of death analysed there was no evidence of an exposure-response relationship. However, the relative risks for mortality, from suicide and non-motor vehicle accidents, increased two fold in the highest category of chlorpyrifos exposure days. Researchers concluded that while these results were based on small numbers they suggested there may be a link between chlopyrifos and depression and other neurobehavioural symptoms and that these links warrant further research.

t'Mannetje et al (2005) cohort study of 1025 Phenoxy herbicide producers and 703 sprayers followed from January 1969 until 31 December 2000, in New Zealand, explored the relation between exposure to dioxin and phenoxy herbicides and mortality. A total of 813 producers and 699 sprayers were classified as exposed to dioxin and phenoxy herbicides. Standardised mortality ratios (SMR) were calculated using national morbidity rates. The results showed 24% non-significant excess cancer mortality in phenoxy herbicide producers, with a significant excess for multiple myeloma. The associations were stronger for those exposed to multiple agents including dioxin during production. Overall, cancer mortality was not increased for producers and sprayers mainly handling final technical products, although they were likely to have been exposed to TCDD levels far higher than those currently in the general New Zealand population.

16.5 Cardiovascular disease

Two studies were found, one cohort study exploring risk factors for cardiovascular disease amongst women farm residents women non-farm residents, and one analysis of routine data exploring the occurrence of ischaematic heart disease (IHD) among male and female livestock workers.

16.6 Summary of studies

- One cohort study of women farm residents and women non-farm residents in the United States aimed to describe the base line difference in cardiovascular disease risk factors for these two groups of women. The results suggested that the prevalence of risk factors for atherosclerosis and future coronary heart disease is very high in rural women. The researchers recommended targeted programmes addressing obesity for rural women and smoking cessation for non-rural women (McCarty et al 2002).

- A Swedish analysis of routine data sought to document the occurrence of ischaematic heart disease (IHD) among male and female livestock and agricultural workers in Sweden. The study results suggested a slightly increased risk for IHD among both male and female livestock workers which may be a result of exposure to organic dust (Sjogren et al 2003).

16.7 The Studies

McCarty et al (2002) cohort study of 675 farm residents and 825 non- farm residents control group aimed to describe base line difference in cardiovascular disease risk factors between farm and non-farm women in a geographically defined area. Baseline examination included measurements of blood pressure, skin folds, height, weight, fasting blood lipids, and blood glucose. Health behaviour data was also collected on smoking, dietary intake, reproductive health, physical activity, medical history, social support, occupational strain, and symptoms of anxiety and depression. Farm residents and non-farm residents were of similar age (mean 47.6 and 47.0). The results suggest that the prevalence of risk factors for atherosclerosis and hence future coronary heart disease is very high in rural women. Researchers recommended that obesity reduction programs should target rural women, and cease smoking campaigns should target non-rural women.

Sjogren et al (2003) drew from the Swedish National Censuses of 1970 and 1990 to identify male and female livestock and agricultural workers, these workers were followed until 1995. Researchers compared the occurrence of ischaemic heart disease (IHD) among male and female livestock and agricultural workers in Sweden, the IHD mortality of livestock and agricultural workers and compared with gainfully employed men and women of Sweden. Information on smoking was gained from a previous national survey. The study suggested a slightly increased risk for IHD among both male and female livestock workers, which may be a result of organic dust exposure.

16.8 Health Status and High risk health behaviours

Two studies were found, both cross sectional surveys, one in the USA and one in New Zealand, both exploring health status and high risk health behaviours.

16.7 Summary of studies

- In the United States a study compared health behaviour between farm, rural non-farm and town households and revealed residents of farm households were younger, better educated and smoked less than residents of rural nonfarm and town households. The men more often had hearing loss, were overweight or obese and more often reported injury and they were also less likely to report asthma and or to see a medical practitioner regularly. Women reported poorer emotional health and had higher rates of depressive symptoms (Merchant 2002).
- In New Zealand a cross sectional survey of individuals on farms explored health status. Researchers reported high levels of injury, low back pain being the most common and noise-induced hearing loss was prevalent amongst men. There were low levels of asthma amongst the men and 19.3% of the male farmers were obese. The prevalence of alcohol use disorder among men aged 15-24 years was 57.4% and

39.0% among farm workers. Thirty-two percent of the men in the 15-24 year age-group smoked with 35% of smokers being farm workers (Firth et al 2001).

16.8 The Studies

Merchant et al (2002) Keokuk County Rural Health Study aimed to describe, measure and analyse prevalent rural and agriculturally related adverse health outcomes and risk factors for rural households both farm and non-farm. The methods employed included In-person interviews, medical screenings, and environmental assessments of home and farms and all of the households surveyed were rural. Comparisons were made between farm, rural non-farm and town households, between men and women, and smokers and non-smokers. The results showed that residents of farm households were younger, better educated and smoked less than residents of rural nonfarm and town households. Men more often reported hearing loss, were more often overweight and obese, more often reported injury, less often reported asthma and were less likely to consult a medical practitioner. Women reported poorer emotional health and higher rates of depression symptoms.

Firth et al (2001) cross-sectional survey of 586 individuals from 286 farms in Southland, New Zealand explored their health status. Researchers reported high levels of injury, with low back pain being common and noise-induced hearing loss prevalent among men. Additionally, there were low levels of asthma and 19.3% of male farmers were obese. The prevalence of alcohol use disorder among men aged 15-24yrs was 57.4% and 39.0% among farm workers. Thirty two percent (32%) of the men aged 15-24 years smoked and 35.6% of farm-workers were smokers.

16.9 Mental Health

Researchers in all three regions have been examining stress, anxiety and depression amongst farmers and farm workers in the period of this review. Particular attention has been paid to the relation between pesticide exposure and depressive symptoms and gendered differences in psychological well being amongst farm residents. Additionally researchers have focused on the psychological health of adolescents in rural areas and suicide rates amongst farmers and agricultural workers, identifying certain age groups and statuses to be more at risk. For example in Australia farm managers 55 years of age and over and agricultural workers aged 15-39 years are high risk groups (Page and Fragar 2000). Social support and networks appear to be important protectors against depression and suicide and there is some evidence that farmers exhibit different health seeking behaviours than non-farmers and that these behaviours might serve as barriers to suicide prevention.

17.0 Summary of studies

- A cohort study in the United Kingdom explored the relation between farming practices and psychiatric morbidity. Only 6% of the farmers reported clinically relevant psychiatric morbidity and this was not associated with the farm type or size of the property. Farmers reported a lower prevalence of psychiatric morbidity than the general population. However, they were more likely to report that life was not worth living. Researchers concluded that the relation between depression and suicidal ideation for farmers appeared to be quite different than that of the general population

and warrants further research (Thomas et al 2003). A retrospective case control study explored the relation between suicide and contact with mental health services prior to death. Researchers found no significant differences between farmers and controls for the numbers in contact with their general practitioners or mental health practitioners' in the three months prior to death. However over 30% of the farmers presented to their general practitioners with exclusively physical symptoms; suggesting quite different health seeking behaviour (Booth 2000). Booth's (2000) survey of farmers in South West England explored occupational stress, anxiety and depression. A significant proportion of respondents showed elevated levels of anxiety and depression - measured by the Hospital Anxiety and Depression Scale (HAD). Most common sources of perceived stress were coping with new legislation, paper work and media criticism. A prevalence study of rural adolescents examined the prevalence of depressive symptoms and sought to identify related social and environmental variables. The prevalence of high level depressive symptoms in this sample was 34%. Researchers concluded that interventions to identify and prevent depressive symptoms in rural adolescents are needed (Peden et al 2005). A prevalence survey of men in England and Wales investigated neuropsychiatric symptoms in past users of sheep dip and other pesticides. Researchers concluded neurological symptoms are more common in men who have worked with sheep dip and that past use of pesticides was not associated with current anxiety or depression (Solomon et al 2007). An analysis of Scottish death records explored suicide and undetermined male deaths of farmers and farm workers in Scotland in the period 1981-1999. Researchers found higher rates of suicide amongst farmers in areas where farming was less common, suggesting the possible importance of social networks and support as protective factors against suicide (Stark et al 2006). Simkin et al (2003) analysed a suicide data set in England and Wales for the period 1982-1999. Researchers examined the relation between seasonality and suicide of male farmers and concluded that there was no significant difference in variation of violent suicides throughout the year and that seasonal variation appeared to be diminishing in this occupation (Simkin et al 2003).

- A case control study in the USA of the female spouses of private pesticide applicators, investigated if there was an association between depression and pesticide exposure among these women. Depression was found to be significantly associated with a history of pesticide poisoning. Beseler's (2006) cross-sectional survey explored the relation between pesticide poisoning and depressive symptoms among farm residents in Colorado. The researchers concluded that exposure to pesticides at a high enough concentration to cause self reported poisoning symptoms was associated with high depressive symptoms independently of other known risk factors for depression among farm residents. A cross-sectional survey of women in Lousianna explored depression amongst farm women. Factors predictive of depressive symptoms included perceived hazards associated with farming, experience of recent farm injuries and being engaged in farming for a long period of time. Having a multitude of responsibilities and environmental and social influences also placed farm women at high risk of depressive symptoms (Carruth et al 2002). A cross sectional

survey of farmers and non-farmers examined anxiety and depression. Farmers were found to have higher levels and prevalence of depression, particularly male farmers, who also had higher levels of anxiety. The differences were greatest between full time farmers and non-farmers. The researchers concluded that farming is associated with increased level of anxiety and increased levels and prevalence of depression. Another cross sectional survey explored the association between pesticide poisoning and depressive symptoms among farm residents. Researchers concluded that exposure to pesticides at high enough concentration to cause poisoning symptoms was associated with high depressive symptoms, independently of other known risk factors for depression among farm residents (Stallones 2006). Another study explored the effects of socio-demographic and acculturation factors on life time psychiatric disorders amongst Indian, non-Indian Mexican farm workers and Mexican migrant farm workers. Life time prevalence of any psychiatric disorder was lower from migrants than for Mexican Americans and for the US population as a whole. High acculturation and primary US residence increased the likelihood of life-time psychiatric disorders (Alderete et al 2000). A prevalence survey in Colorado explored the relation between depression and somatic symptoms. Researchers concluded that both psychological and physical symptoms significantly correlated with depression, with psychological factors being more strongly correlated. Only minor differences were found between women and men (De Armond et al 2006). Scarth et al (2000) prevalence survey compared risk factors and depressive symptoms and found farmers in Iowa had a 1.74 times higher level of depression than farmers in Colarado. Researchers concluded that farmers in Iowa had higher risk because of substantial income decline (Scarth et al 2000).

- In Australia a prevalence survey of farmers and non-farming rural residents investigated the rate of mental health problems and explored possible associations with increased rates of suicide amongst farmers. Researchers concluded that the elevated rate of suicide amongst farmers does not appear to be explained by an elevated rate of mental health problems. Health seeking behaviour – and a person's ability to talk about mental health problems in particular, appear to be significant risk factors for suicide in farmers (Judd et al 2006). A case series study investigated the relation between farming as an occupation and mental health problems. Researchers concluded that farmers do not have higher levels of mental health problems than non-farmers. Farmers were more psychologically healthy, have a higher physical health state and lower levels of disability and distress associated with mental health problems when compared with rural non-farmers. Researchers suggested that certain personality traits might buffer farmers from distress (Judd et al 2006). Page et al (2007) analysis of routine data explored rural suicide rates in the 1979-2003 period. Urban rural differences were statistically significant and the largest urban rural male suicide differentials for the 25 year period occurred in the most recent period (1999-2003), where there were increases amongst males aged 15-24 years in remote areas (a 23% increase) in the context of decreasing male suicide rates overall (Page et al 2007). An analysis of suicide data for farm managers and agricultural labourers in the period 1988-1997 identified the majority to be of farm managers and amongst those

over the age of 55 years. Suicides amongst the agricultural labourers were in younger age groups with the majority in the 15-39 age grouping. Male farm manager and agricultural labourer suicide rates are higher than male national rates and suicide rates in the wider rural population (Page and Fragar 2002).

- In New Zealand a cross sectional survey explored stress amongst farmers. The most stressful events were 'increased workload at peak times' 'dealing with workers' compensation'; 'bad weather' and 'complying with health and safety legislation'. There were differences between men and women, and higher stress was associated with age, being separated or divorced, being a deer farmer, the economic viability of the farm and supervising staff (Firth et al 2007). A cross-sectional study of dairy farmers examined stress and stress associated with new technology. High levels of stress were associated with time pressures, machinery breakdown, but rarely in response to new technology (Alpass et al 2001).

17.1 The Studies

Thomas et al (2003) cohort study of 425 farmers from Hereford, Norwich, Preston estimated the prevalence of neurotic symptoms and relation between farming characteristics and psychiatric morbidity. Four hundred and twenty five (n=425) farmers completed the Revised Clinical Interview Schedule (CIS-R) by computer between March and July 1999. The comparison cohort consisted of 9830 private householders aged 16-64 years and was taken from the Office of Population Censuses and Surveys National Psychiatric Morbidity Surveys of Great Britain carried out in 1993 in which CIS-R was administered. Only 6% of farmers reported clinically relevant psychiatric morbidity and this was not associated with farm type or size in this study. Farmers reported a lower prevalence of psychiatric morbidity than the general population, however they were more likely to report that life was not worth living, particularly after the low prevalence of psychiatric morbidity had been taken into account (odds ratio 2.56, 95% CI 1.39 to 4.69). When rural or semi-rural householders were compared this increased risk was even more pronounced (odds ratio 3.26, 95% CI 1.51 to 7.02). The researchers concluded that the relation between depression and suicidal ideation for farmers seems to be quite different than that of the general population and warrants further research.

Beseler et al (2006) case control study of 29 074 female spouses of private pesticide applicators in the period 1993-1997 investigated if there was an association between depression and pesticide exposure among women. Cases comprised those women who had physician diagnosed depression requiring medication. Life time pesticide use was categorised as never mixed/applied pesticides, low exposure (up to 225 days), high exposure (>225days) and a history of diagnosed pesticide poisoning. Results were adjusted for age, state, race, off-farm work, alcohol, cigarette smoking, physician visits and solvent exposure. Depression was significantly associated with a history of pesticide poisoning and the researchers concluded that pesticide poisoning may contribute to risk of depression.

A retrospective case control study of 63 farmer suicides and 63 non-farmer suicide controls explored the relation between suicide and contact with primary or mental health services prior to death. Researchers compared male farmers with an age and sex matched control

group. Cases were identified through an administrative data base where suicide was an open verdict (Exeter Health District) in the period 1979-1994. Farmers represent 1% of suicides in England and Wales. There were no significant differences between farmers and controls for the numbers in contact with their general practitioner or mental health services in the three months before death. Researchers concluded however, that there may be some differences in health seeking behaviour between the two groups; as over 30% of farmers presented to their general practitioners with exclusively physical symptoms. Farmers were more likely to use firearms (42% compared to 11% controls) and significantly less likely to leave a note (21% farmers, 41% controls) (Booth et al 2000).

Beseler (2006) cross-sectional survey of 761 farmers and spouses in Colorado explored the relation between pesticide poisoning and depressive symptoms among farm residents. Exposure to pesticides at a high enough concentration to cause self reported poisoning symptoms was associated with high depressive symptoms independently of other known risk factors for depression among farm residents.

A survey of farmers in South West England explored occupational stress, anxiety and depression. Researchers reported 35% of respondents scored positively on the General Health Questionnaire (GHQ) with female respondents showing significantly higher scores than males. A significant proportion of respondents showed elevated levels of anxiety and depression - measured by the Hospital Anxiety and Depression Scale (HAD). The most common sources of perceived stress were coping with new legislation, paper work and media criticism (Booth 2000).

A survey of farm women in south east Louisiana explored the incidence of depressive symptoms. Factors predictive of depressive symptoms in adjusted logistic regression included those who experienced poor health; perceived hazards associated with farming, experienced recent farm injuries and those who had been engaged in farming over a long period of time. In addition, other factors included women who had a multitude of responsibilities and environmental and other social influences that placed farm women at high risk for depressive symptoms (Carruth et al 2002).

Firth et al (2007) a cross sectional survey of 1015 farmers in New Zealand explored stress among New Zealand farmers and examined stressors, health and coping. The most stressful events were 'increased workload at peak times, 'dealing with workers' compensation', 'bad weather', and 'complying with health and safety legislation'. The researchers found differences between men and women and higher stress was associated with: age, being separated or divorced, being a deer farmer, the farm not making a profit in the last year, and supervising staff.

Another cross sectional study of dairy farmers (n=985) in New Zealand examined stress and stress associated with the adoption of new technology using a twelve item stress questionnaire. The results showed that the highest levels of stress were experienced over time pressures, machinery breakdown, but only rarely in relation to adopting new technologies (Alpass et al 2004).

In order to examine anxiety and depression in farmers and non farmers, Sanne et al (2004) conducted a cross sectional survey of 17 295 people, of which 917 were farmers. The results showed farmers had higher levels and prevalence of depression, particularly male farmers, who also had higher anxiety levels. Male farmers reported longer working hours, lower income, higher psychological job demands and less decision latitude when compared with non-farmers. Farmers performed physically heavier work and had lower levels of education. The differences in levels of anxiety and depression were greatest between full-time farmers and non-farmers. The researchers concluded that farming was associated with increased levels of anxiety and increased levels of and prevalence of depression.

A cross sectional survey of 761 farmers and spouses in Colorado explored the association between pesticide poisoning and depressive symptoms among farm residents. Exposure to pesticides at high enough concentration to cause self reported poisoning symptoms was associated with high depressive symptoms independently of other known risk factors for depression among farm residents (Stallones 2006).

In a prevalence survey of 1001 farm workers aged between 18-59 years researchers explored risk factors for psychiatric disorders amongst Indian, non-Indian Mexican farm workers and Mexican migrant farm workers in California. A modified version of the Composite International Diagnostic Interview was used for case ascertainment and the effects of socio-demographic and acculturation factors on life time psychiatric disorders were tested. The results showed that a life time prevalence of any psychiatric disorder was lower for migrants than for Mexican Americans and for the US population as a whole. High acculturation and primary US residence increased the likelihood of life-time psychiatric disorders. The results underscore the risk posed by acculturation and or the acculturation process, the potential for progressive deterioration of this population's mental health, and the need for culturally appropriate mental health services (Alderete et al 2000).

A prevalence survey of 709 farm operators and spouses in north-eastern Colorado explored the relation between depression and somatic symptoms. Exploratory and confirmatory factor analyses were conducted on the symptom inventory and suggested a two factor structure (psychological, physical). Both psychological and physical symptoms were significantly correlated with depression, with psychological factors being more strongly correlated. Only minor differences between men and women were found (De Armond et al 2006).

Judd et al (2006) prevalence survey of 371 farmers and 380 non-farming rural residents in Australia investigated the rate of mental health problems amongst farmers compared with non-farmer rural residents and possible associations with increased rates of suicide amongst farmers. Semi structured interviews were also conducted with 32 farmers. Researchers concluded that the elevated rate of suicide amongst farmers does not appear to be explained by an elevated rate of mental health problems. Individual personality, gender and community attitudes that limit a person's ability to acknowledge or talk about mental health problems and seek help may be significant risk factors for suicide in farmers.

In another prevalence study of 299 rural adolescents aged 14-18 researchers examined the prevalence of depressive symptoms and sought to identify related social and environmental variables. The survey explored social and environmental information and required the completion of the Center for Epidemiological Studies Depression Scale (CES-D), as well as scales to assess the number of major life events in the last year, active coping use and family closeness. The prevalence of high level depressive symptoms in this sample was 34% and the researchers concluded interventions to identify and prevent depressive symptoms in rural adolescents are needed (Peden et al 2005).

Scarth et al (2000) prevalence survey of 385 Iowa farmers and 470 Colarado farmers compared risk factors and depressive symptoms (evaluated using the CES-D scale). Although Iowa farmers had a 1.74 times higher level of depression symptoms than the Colarado farmers, this difference was not significant after adjusting for higher levels of risk amongst Iowa farmers. The researchers noted that farmers in Iowa had twice the frequency of substantial income decline and this was possibly related to the higher level of depressive symptoms.

A prevalence survey of 9844 men in England and Wales investigated the prevalence and pattern of neuropsychiatric symptoms in past users of sheep dip and other pesticides. The research protocol included a postal survey of men born between 1933 and 1977 and resident in three rural areas in England and Wales. Life time work history of work with pesticides, neurological symptoms in the past month, current mental health and tendency to be troubled by non-neurological somatic symptoms were recorded. Risk factors were assessed by modified Cox Regression. Researchers concluded neurological symptoms are more common in men who have worked with sheep dip. Past use of pesticides was not associated with current anxiety or depression (Solomon et al 2007).

Judd et al (2006) case series study of 371 farmers and 380 rural non-farmers investigated the relation between farming as an occupation and mental health problems. The results showed farmers did not experience higher levels of mental health problems when compared to non-farmers. The researchers concluded that farmers were more psychologically healthy, had a higher physical health state and lower levels of disability and distress associated with mental health problems compared with rural non-farmers. Additionally, significant differences in personality traits were found and the researchers suggested that certain personality traits may buffer farmers from distress.

Page et al (2007) drew from a suicide data set in Australia to investigate changes in Australian urban-rural suicide rates between 1979 and 2003. Suicide data were stratified for the period 1979-2003 by metropolitan, rural and remote areas and examined across five quinquennia, centred on each Australian census from 1981-2001. Rates were adjusted for confounding by age, sex, country of birth and the mediating effects of area SES using Poisson Regression Models. Urban rural differences were statistically significant and the largest urban-rural male suicide differentials for the 25 year study period occurred in the most recent period (1999-2003), in the context of decreasing male suicide rates overall. There were

increases for males aged 15-24 yrs and increases in remote areas were significant, with an increase from 38.8 per 100 000 to 47.9% in this period.

Page and Fragar (2002) drew from a suicide data set in Australia to identify and describe suicide data for occupational classifications relating to farm managers and agricultural labourers between 1988 and 1997 in Australia. Nine hundred and twenty one (n=921) suicides were identified for this period. The majority were amongst farm managers and amongst those 55 years and over. Agricultural labourer suicides were in the younger age groups, with the majority occurring in the 15-39 year age group. The most common methods involved firearms, hanging and motor vehicle exhaust gas. These three methods accounted for 81% of male suicides in this period. Male farm manager and agricultural labourer suicide rates are higher than male national rates and rates in the wider rural population, particularly in the latter years investigated.

Stark et al (2006) analysis of Scottish death records in the period 1981-1999 explored suicide and undetermined death in male farmers and farm workers in Scotland. Deaths of men aged 15-74 years from suicide or undetermined cause were identified and came to a total of 307 during this period. The overall rate was 31.4 /100 000 per year (95% CI 28.1-35.1). Researchers argued that the availability of firearms on farms appears to contribute to suicide rates, however, researchers also found higher rates of suicide amongst farmers in areas where farming is less common. Researchers suggested that networks and social support may be important protective factors against suicide, given that rates are higher in areas where farming is less common.

Simkin et al (2003) analysed a suicide data set in England and Wales for the period 1982-1999 to explore the relation between seasonality and suicide rates of male farmers. Seasonal patterns of suicide in farmers and non-farmers were examined by nonparametric tests and harmonic analysis. No significant seasonal variation was found for farmers and there was no significant difference in the variation of violent suicides throughout the year. The researchers concluded that seasonal variation appeared to be diminishing in this occupation.

17.2 Osteoarthritis

The search found three studies, one cohort study, one cross sectional survey and one analysis of routine data that investigated occupational osteoarthritis.

17.3 Summary of studies

- In Sweden a cohort study investigated the risk of developing osteoarthritis of the hip joint from occupational use. Researchers concluded that farmers, but not non-farming rural men, had a significantly increased risk of developing osteoarthritis of the hip joint when compared with urban referents (Thelin 2007). In France a cross sectional survey investigated occupational prevalence and risk of osteoarthritis. The results suggested that osteoarthritis is potentially aetiologically linked to occupation. Agricultural workers showed a significant excess prevalence in osteoarthritis (Rossignol 2003). An analysis of routine data in France aimed to identify the prevalence of osteoarthritis of the knee, hip and hand and to identify biomechanical

stresses and severity. Agricultural male and female workers were identified as amongst those with greater prevalence (Rossignol et al 2005).

17.4 The studies

A cohort study of 1220 farmers; 1330 matched rural non-farming men, and 1087 urban men in Sweden, investigated the risk of developing osteoarthritis of the hip joint from occupational use. The sample was identified and obtained in 1989 from a Swedish register of hospital care and surgery and followed up over time. The researcher concluded farmers, but not non-farming rural men, had a significantly increased risk of developing osteoarthritis of the hip joint when compared with urban referents (Thelin 2007).

Rossignol (2003) cross-sectional survey of 10 412 patients in France investigated occupational prevalence and risk of osteoarthritis (OA). The results of this study contribute to mounting evidence that OA is potentially aetiologically linked to occupation. Agricultural workers showed a significant excess prevalence in OA, with an observed prevalence odds ratio of 1.7 in women and 2.3 in men. Total work disability was highest among blue collar workers and partial disability among agricultural workers.

Patients presenting with osteoarthritis of the knee, hip or hand in France were identified through an administrative data base. Researchers aimed to identify occupations with excess prevalence of osteoarthritis of the knee, hip and hand and to identify biomechanical stresses and severity. This nation-wide survey identified occupations with the greatest prevalence rate ratio were female cleaners, women in the clothing industry, male masons and other construction workers and agriculture male and female workers. Early onset was observed in heavier labour jobs with first symptoms before the age of 50 years (Rossignol et al 2005).

17.5 Pesticide Exposure

The search found studies which explored exposure to pesticides and significant risk factors, these studies included three case control studies and two cross sectional studies in the USA and one cross sectional survey and one prevalence survey, in the United Kingdom.

17.6 Summary of studies

- A case control study in the United States explored exposure to pesticides and risk factors. Significant risk factors included poor financial condition of the farm and a high score on a risk acceptance scale (Alvanja et al 2001). A nested case control analysis of high pesticide exposure events among farmers, non farmers and farmer spouses and non farmer spouses in Iowa and North Carolina found that pesticide applicators in Iowa had a much greater high pesticide exposure event score than applicators in North Carolina (Bell et al 2006). A study explored pesticide contamination in homes and found that distributions of pesticides in various rooms suggested that strictly agricultural herbicide, atrazine and metoachlor, are potentially being brought into homes on farmers shoes and clothing (Curwin et al 2005). A cross sectional study explored the relation between safety practice, neurological symptoms and pesticide poisoning. The associations between safety practices and neurological symptoms were increased in the presence of pesticide poisoning and failure to engage

in safety practices were neurological symptoms (Beseler, 2003, 2006). A cross sectional survey of male pesticide applicators explored exposure to pesticides and neurotoxicity. The greatest risk was with the use of organophosphate and organochlorine insecticides. Researchers concluded that neurologic symptoms associated with cumulative exposure to moderate levels of organophosphate and organochlorine insecticides were evident regardless of recent exposure history of poisoning (Kamel et al 2007).

- In the United Kingdom a cross sectional survey of sheep dipping farmers and farmers with no sheep dipping experience and ceramic workers tested the hypothesis that chronic low level exposure to organophosphates in sheep dips is related to clinically detectable measures of polyneuropathy. Researchers concluded that long term health effects may occur in some sheep dippers exposed to organophophates over a working life time, but the mechanisms for this remain unclear (Pilkington 2001). A prevalence survey of farmers explored the association of exposure to organophosphates and the development of chronic fatigue. Higher chronic fatigue scores were associated with higher exposure to organophosphate pesticides (Tahmaz et al 2003).

17.7 The studies

Alvanja et al (2001) conducted a case control study of 5 970 farmer applicators in Iowa, of which 36 met the criteria of high pesticide exposure events. The criteria included reporting an incident with fertilizers, weed killers and other pesticides that caused an unusually high personal exposure which resulted in physical symptoms or a visit to a health care provider or hospital. Significant risk factors included: poor financial condition of the farm, a high score on a risk acceptance scale, however the researchers noted that it was a statistically weak sample.

Bell et al (2006) conducted a nested case control analysis of high pesticide exposure events (HPEEs) among Iowa farmers (306), non-farmers (612), farmer spouses (63) and non-farmer spouses (126). The researchers performed an analysis of factors associated with reporting a high pesticide exposure event by pesticide applicators and their spouses during the five years since enrolment in the Agricultural Health Study study in Iowa and North Carolina. Pesticide applicators in Iowa had a much greater HPEE (8.8/1000 applicators) than applicators in North Carolina (2.0/1000) and spouses reported (2.0/1000) exposure events. Only 13% of applicators and 22% of their spouses with symptoms resulting from HPEE sought medical care, suggesting under-reporting in surveillance data.

Another case control study of 25 farm households and 25 non-farm households in Iowa investigated pesticide contamination inside homes. Air, surface wipe, and dust samples were collected and samples from 39 homes were analysed (20F, 19 NF) for atrazine, metolachlor, acetochlor, alachlor, and cholopyrifos. Samples from 11 homes (5F and 6NF) were analysed for glyphosphate and 2.4 Dciholorophenoxyac etic acid (2.4D). The distributions of the pesticides throughout the various rooms sampled suggest that the strictly agricultural herbicides atrazine and metoachlor are potentially being brought into the home on the farmer's shoes and clothing, that is, they appear to be getting into the home para-occupationally (Curwin et al 2005).

A cross-sectional study, in an 8 county area in Colarado, surveyed farmers and their spouses and explored the relations between safety practice; neurological symptoms and pesticide poisoning. Multivariate logistic regression models were used to determine associations between safety practices, neurological symptoms and pesticide poisoning. The associations between safety practices and neurological symptoms (difficulty concentrating, feeling irritable, memory difficulties and trouble reading) were increased in the presence of pesticide poisoning and the researchers concluded that failure to engage in safety practices was a neurological symptom (Beseler 2006).

In another cross-sectional survey of 18 782 caucasian, male, pesticide applicators in Iowa and North Carolina (AHS) researchers explored exposure to pesticides and neurotoxicity. Participants provided information on pesticide use and 23 neurologic symptoms typically associated with pesticide toxication. Increased risk of experiencing symptoms was associated with cumulative pesticide use, personally mixing or applying pesticides, pesticide related medical care, diagnosed pesticide poisoning and events involving high personal pesticide exposure. The greatest risk was with use of organophosphate and organochlorine insecticides. Groups of symptoms affecting: cognition, autonomic and motor function and vision were associated with pesticide exposure. Neurologic symptoms were associated with cumulative exposure to moderate levels of organophosphate and organochlorine insecticides, regardless of recent exposure history of poisoning (Kamel et al 2007).

Pilkington et al (2001) cross sectional survey of 612 sheep dipping farmers, 53 farmers with no sheep dipping experience and 107 ceramic workers tested the hypothesis that chronic low level exposure to organophosphates (OPs) in sheep dips is related to clinically detectable measures of polyneuropathy. Results were adjusted for confounders and the findings showed a strong association between exposure to OP concentrate and neurological symptoms, but a less consistent association with sensory thresholds. There was only weak evidence of a chronic effect of low dose cumulative exposure to OPS. Long term health effects may occur in a least some sheep dippers exposed to OPs over a working life time. But researchers concluded that the mechanisms for this remain unclear.

Tahmaz et al (2003) prevalence survey of 206 farmers in the United Kingdom explored the association of exposure to organophosphates and the development of Chronic Fatigue. Participants responded to two questionnaires; the first identifying the history of exposure and then their exposure was reconstructed using a metric specifically developed for this purpose. The second questionnaire identified whether the subject had Chronic Fatigue when they reported to the surveillance scheme and or when the participated in the survey. Higher Chronic Fatigue scores were associated with higher exposure to organophosphate pesticides and the researchers concluded that further research is necessary.

17.8 Parkinson's disease

The search found one case control study that investigated associations between Parkinson's disease and pesticide exposure.

17.9 Summary of studies

- A case control study of cases of cases of Parkinsonism and controls in Scotland, Italy, Sweden, Romania and Malta investigated associations between the disease and environmental factors. Researchers concluded the association of pesticide exposure with Parkinson disease suggests a causative role and that repeated loss of consciousness is associated with increased risk of developing Parkinson's disease (Dick et al 2007).

Dick et al (2007) case control study of 959 prevalent cases of parkinsonism (767 with Parkinson's disease) and 1989 controls in Scotland, Italy, Sweden, Romania and Malta investigated the associations between Parkinson's disease and other degenerative parkinsonia syndromes and environmental factors in five European countries. Cases were defined using the United Kingdom Parkinson's Disease Society Brain Bank criteria with those with drug induced or vascular parkinsonism or dementia being excluded from the sample. An interviewer administered questionnaire about life time occupational and hobby exposure to solvents, pesticides, iron, copper and manganese was conducted. Multiple logistic regression adjusting for age, sex, country, tobacco use, ever knocked unconscious and family history of Parkinson's disease suggested the association of pesticide exposure with Parkinson's disease is causative and that repeated traumatic loss of consciousness is associated with increased risk of Parkinson's disease.

18.0 Leptospirosis

The search found one study that explored current trends in human letptospirosis in New Zealand.

18.1 The Study

Thornley et al (2002) examined surveillance and disease notification data from 1990 to 1998 in New Zealand in order to describe current epidemiology and trends in New Zealand human leptospirosis. The incidence of human leptospirosis in New Zealand remains high for a temperate developed country. Incidence was highest amongst meat processing workers, livestock farm workers and forestry related workers. Increasing Leptospira borgpetersenii serovar - Ballum case numbers suggested changing transmission patterns via direct or indirect exposure to contaminated water.

18.2 Summary and overview of risk and exposure to disease in agriculture

The best evidence for assessing possible causal relationships between exposure and disease comes from cohort studies. The majority of these have dealt with chemical exposure and the risk of cancer. The main problem is the range of chemicals, both pesticides and herbicides, in use on the farm, and the other is the development and application of exposure metrics. Examination of multiple exposures can give rise to associations by chance, and multiple exposure metrics can also be applied, for example using cumulative or intensity measures. If these do not have biological plausibility it can also lead to spurious associations. The results of cohort studies have been equivocal. Malathion, the most common orgnophosphate pesticide used in the USA, has not been associated with cancer. The organochlorine pesticides (diazinon, and dieldrin) have been associated with lung cancer, but only at the

highest exposure levels. Similarly, Alachlor has been associated with lymphohaematopoietic cancers, with multiple myeloma and leukaemia raised at the highest exposure levels. Other exposures studied have included Cyanazine (no effect) and Carbaryl where a small increase in Non Hodgkin's Lymphoma (NHL) risk using some exposure measures was found.

There have been many more case-control than cohort studies, this is possibly because they are easier to conduct and cost less to conduct. However, they are more susceptible to bias, particularly recall bias (i.e. those who have a cancer are more likely to recall exposures). Population studies also tend to examine the risk for multiple occupations. Case-control studies are most suited to examining the association between a particular disease and exposure. Lymphohaematopoietic cancers including non Hodgkin's lymphoma have been subject to the most scrutiny, and the association with organochlorines, organophosphates and herbicides have been assessed. The results of most are, once again, equivocal, although the suggestion that zoonoses may be responsible for the increased risk of lymphohaematopoietic cancers in farmers and freezing workers is biologically plausible.

There have been few cohort studies assessing respiratory disease, with some evidence of an association between pesticides and self reported "wheeze", which is more common than asthma requiring treatment. Most studies of respiratory and other disease have been "prevalence" studies, of quasi case-control design or cross sectional surveys. Some of these studies have shown associations between respiratory obstruction and dust, including animal dust and dander, but there has also been a suggestion that exposures on the farm may be protective against occupational asthma.

Musculoskeletal disease has been the subject of a number of cohort studies, and farming has been associated with osteoarthritis of the hip. Case-control studies have also shown some evidence that osteoarthritis of the knee may be more common amongst those who farm. Whole body vibration has also been associated with musculoskeletal diseases, particularly Osteoarthritis of the hip.

Case-control and cross sectional studies have also examined the relationship between pesticide use and neurological symptoms, with reasonable evidence that organophosphate exposure is associated with neurological symptoms.

In summary, the evidence that farmers have an increased risk of cancer is equivocal, although there are plausible associations between lymphohaematopoietic cancers and chemicals, and perhaps more so with zoonoses. There is reasonable evidence that some farm exposures, especially biological agents, may give rise to respiratory disease; that organochlorine pesticides may be associated with neurological dysfunction; and that farmers are more prone to musculoskeletal disorders.

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Appendix A

Risk factors for work-related agricultural injury and disease: a summary of study designs

Study design	Author/date	Location of the study	Type of injury/disease and population
Cohort (retrospective & prospective)			
	Bancej (2000)	Ontario, Canada	Children aged 0-18 on 1,765 family operated farms
	Freeman et.al. (2005)	Iowa and North Carolina	Licensed pesticide applicators, 23,106 males
	Blair et.al. (2005)	Iowa and North Carolina	Licensed pesticide applicators and their spouses, cohort of 89,658 between 1993-1997
	Blair et.al. (2005)	Iowa and North Carolina	Mortality experience of licensed pesticide applicators and their spouses.
	Bonner et.al. (2005)	Iowa and North Carolina	Malathion exposure and incidence of cancer among 19 717 pesticide applicators.
	Bonner et.al. (2005)	Iowa and North Carolina	Licensed pesticide applicators, 49,877
	Carlson et.al. (2005)	Mid-west five state region	tractor related, 3,765 agricultural households
	Chaudemanche et.al. (2003)	France	Respiratory status in dairy farmers in France.
	De Roos AB et.al. (2005)	Iowa and North Carolina	Cancer incidence among Glyphosphate-exposed pesticide applicators. 57 311 licensed applicators.
	Dinham B. (2005)	?	pesticides and lung cancer
	Engel et.al. (2005)	Iowa and North Carolina	30,454 women, pesticide use and risk of breast cancer
	Flower et.al. (2006)	Iowa and North Carolina	Causes of mortality among 21,360 children (1975-1998)
	Gainet et al (2007)	France	Twelve year longitudinal study of respiratory status of dairy farmers.
	Gomez et.al. (2003)	12 New York Counties	1706 participants, musculoskeletal conditions, owner-operators and workers
	Hoppin et.al. (2002)	Iowa and North Carolina	20,468 pesticide applicators, age range 16-88 years. Relationship between pesticides and respiratory symptoms of farmers.
	Hoppin et.al. (2003) al. (2003)	Iowa and North Carolina	Exposure to animals, feeds and byproducts and respiratory symptoms amongst farmers. 20 468 farmers.
	Hoppin et.al. (2004)	Iowa and North Carolina	Exposure to nonpesticide occupational exposures (solvents, exhaust fumes) and adverse respiratory effects.
	Hoppin et.al. (2006)	Iowa and North Carolina	89 000 licensed pesticide applicators and their spouses; association of pesticides with respiratory outcomes, including wheeze, adult asthma, farmer's lung, and chronic bronchitis.
	Hoppin et.al. (2006)	Iowa	2,255 Iowa commercial pesticide applicators, association with wheeze.
	Hou et.al. (2006)	Iowa and North Carolina	Pendimethalin exposure and cancer incidence amongst pesticide applicators. 9089 exposed, 15 285 non-exposed.
	Inverson (2000)	Denmark	Working in swine-confinement buildings casues an accelerated decline in FEB1, seven year follow up study of Danish farmers.
	Koutros et.al. (2008)	Iowa and North Carolina	Dichlorvos exposure and human cancer risk. 49 762 licensed applicators, 4 613 reported use.
	Lee et.al. (2007)	Iowa and North Carolina	Evaluate whether agricultural chlorpyrifos exposure is related to mortality. 55,071 pesticide applicators

	Lee et.al. (2004)	Iowa and North Carolina	Exposure to alachlor and incidence of cancer amongst 49 980 pesticide applicators.
	Lee et.al. (2007b)	Iowa and North Carolina	Relationship between agricultural pesticides and colorectal cancer amongst 56 813 pesticide applicators with no prior history of colorectal cancer.
	Lynch et.al. (2006)	Iowa and North Carolina	Cancer incidence among pesticide applicators exposed to cyanazine. 57311 licensed applicators.
	McCarty et.al. (2002)	Wisconsin	Comparison of cardiovascular disease risk factors in farm and non-farm residents. Women aged 25-75 years; 825 nonfarm and 675 farm residents.
	Mahajan et.al. (2007)	Iowa and North Carolina	Carbaryl exposure and incidence of cancer. 21 416 subjects (1 291 cases).
	Mahajan et.al. (2006)	Iowa and North Carolina	Incident of cancer amongst 45 372 pesticide applicators.
	Mahajan et.al. (2006)	Iowa and North Carolina	Relationship between use of organophosphate pesticide phorate and risk of prostate cancer amongst licensed restricted use pesticide applicators.
	Mannetje et.al. (2005)	New Zealand	Mortality in New Zealand workers exposed to phenoxy herbicides and dioxins.
	Merchant et.al. (2002)	USA	Chronic disease and injury in Keokuk County (20 year)
	Merchant et.al. (2005)	USA	Asthma and farm exposures in a cohort of rural Iowa children.
	Musken et.al. (2000)	German farmers	Sensitisation to mite species in farmers and allergic airways disease. 86 German farmers.
	Nordby et.al. (2004)	Norway	Lip cancer associations with work environmental exposures. 131 243 male Norwegian farmers born 1925-1971.
	Park et.al. (2001)	Iowa	Work related injury rate, depressive symptoms and hours working with animals. 290 Iowa male principal farm operators
	Shipp et.al. (2007)	Texas	Severe back pain among farm worker high school students in Texas. Web based survey of 2536 students; 410 were farmworkers (largely Hispanic and Migrant).
	Solecki (2003)	Poland	Occupational hearing loss among private farmers, 31 family farms.
	Sprince et al (2000)	Iowa	Risk of respiratory symptoms associated with pesticides, silos and animal confinement.
	Thelin (2007)	Sweden	Hip osteoarthritis in a rural male population. Cohort followed over 13 years.
	Thomas et al (2003)	United Kingdom	Mental health of British farmers
	Toren et al (2002)	Sweden	Tractor driving and self reported low back pain and hip symptoms.
Case Control Studies			
	Alavanja et.al. (2001)	Iowa	Nested case-control study of high pesticide exposure events amongst Iowa farmers. 12 month study, 5,970 farmers randomly selected.
	Alexander et.al. (2005)	USA	Farming exposure and early onset prostate cancer. Diagnosed under 60yrs n=1198, 60-79 years n=385.
	Ascota MS et.al. (2007)	Texas	Health risk behaviours and work injury among Hispanic adolescents and farmworkers. 4914 ninth graders (14-15 year olds).
	Bell et.al. (2006)	Iowa	Nested case-control study of the factors associated with high pesticide exposure event by pesticide applicators and their spouses. 16 415 applicators and 14 045 spouses.
	Beseler CSL (2003)	Eight county area-Colarado	The relationship between safety practices, neurological symptoms and pesticide poisoning. Survey of farm residents
	Beseler et.al. (2006)	Iowa and North Carolina	Nested case-control study of the association between depression and pesticide exposure among women. 29 074 female spouses of private pesticide applicators.
	Booth N et.al. (2000)	Exeter	Suicide in the farming community: methods used and contact with health services.

Carlson et.al. (2006)	USA	Examined associations between parents and children's agricultural injuries. Population based nested case control study, involving 3765 agricultural households, data collected over 12 months. 203 injured child cases and 755 randomly selected control children.
Carreon et.al. (2005)	USA	Gliomas and farm pesticide exposure in women: the Upper Midwest Health Study. 341 female glioma cases and 528 controls (18-80 years old).
Curwin et.al. (2005)	Iowa	Agricultural pesticide contamination inside homes. Twenty five farm households and 25 non-farm households.
Dick et.al. (2006)	5 European countries	Environmental risk factors for Parkinson's disease and parkinsonism. 959 prevalent cases (767 with Parkinson disease) and 1989 controls in Scotland, Sweden, Romania and Malta.
Donham et.al. (2007)	USA	Injury and illness costs; evaluation of a cost effectiveness of a safe farm intervention programme.
Duell et.al. (2000)	North Carolina	Farming and pesticide exposure and breast cancer. 862 cases and 790 controls.J25+J25
Golec et.al. (2003)	Poland	Health effects of exposure to Thyme dust in Thyme growing farmers. 47 Thyme farmers and 63 urban dwellers not exposed to Thyme dust.
Franklin & Davies (2003)	Australia	All farm related injury presenting to hospital. Tamworth, New South Wales.
Fritschi et.al. (2005)	Australia	Occupational exposures to pesticides and risk of non-Hodgkin's lymphoma. 694 cases and 694 controls.
Fritschi et.al. (2007)	Australia	Occupational exposures with risk of prostate cancer and with risk of benign prostate hyperplasia.
Hartmann et.al. (2006)	Holland	Risk factors for sick leave due to musculoskeletal disorders among self employed Dutch farmers.
Holmberg & Thelin (2004)		Risk of knee osteoarthritis among farmers. Population based case-control study. 778 subjects and 695 matched controls.
Jamal et.al. (2002)		A clinical neurological, neurophysiological and neuropychological study of sheep farmers and dippers exposed to organophosphate pesticides.
Lee et.al. (2004)	USA	Agricultural pesticide use and adrenocarcinomas of the stomach and oesophagus. Nebraska.
Nordby (2005)	Norway	Physical activity, blood lipid profiles and favourable health outcomes for farmers. N=284.
t'Mannetje et.al. (2008)	New Zealand	High risk occupations for non Hodgkin's lymphoma in New Zealand. 291 cases, 471 controls.
Mester et.al. (2006)	Germany	Occupation and malignant lymphoma in Germany. N=710 aged 18-80 years.
Meyer et.al. (2007)	USA	Farming and prostate cancer in African-American and Caucasian men.
Mills et.al. (2003)	California	Occupational risk factors for prostate cancer amongst Hispanic farm workers in California.
Mills et.al. (2005)	California	Risk factors for lymphohematopoeitic cancers in Hispanic farm workers in California. Nested case control study embedded in a cohort of 139 000 members of a farm workers labor union in California.
Provost et.al. (2007)	France	Brain tumours and exposure to pesticides in southwestern France. 442 cases and 442 controls.
Rafnsson (2005)	Iceland	Prostate cancer and sheep owners exposed to hexachlororcyclohexane.
Ruder et.al. (2004)	USA	Gliomas and farm pesticide exposures in men, Iowa, Michigan, Minnesota and Wisconsin. 457 glioma cases and 648 population based controls.
Ruder et.al. (2006)	Midwestern States	A case control study of primary intracranial gliomas in the farm and rural residents. 1175 controls;798 cases.
Rusiecki et.al. (2005)	Iowa and North Carolina	Cancer incidence among pesticide applicators exposed to permethrin. N=57 311 applicators.
Scarth et.al. (2000)	Colorado	Prevalence of depressive symptoms and risk factors among Iowa and Colorado farmers. 385 Iowa farmers; 470 Colorado farmers (principal operators).
Senthilselvan et.al. (2007)	Saskatchewan	Respiratory health effects of working in swine operations. Male and female workers employed full time in large scale intensive swine operations in Saskatchewan.

	Sprince et al. (2003)	Iowa	Risk factors for agricultural injury among Iowa farmers. 6 999 farmers surveyed.
	Sprince et.al. (2003b)	Iowa	Risk factors of workrelated fall injury amongst Iowa Farmers. 6 999 farmers surveyed.
	Sprince et.al. (2002)	Iowa	Risk factors for machinery-related injuries amongst Iowa farmers. 6 999 farmers surveyed.
	Sprince et.al. (2003c)	Iowa	Risk factors for animal related injuries. 6 999 farmers surveyed.
	Sprince et.al. (2007)	Iowa	Risk factors for low back injury among Iowa farmers. 6 999 farmers surveyed.
	Thomas et.al. (2003)	Hereford, Norwich, Preston	Prevalence of neurotic symptoms amongst 425 British farmers, compared with 9830 private householders.
	Valcin et.al. (2007)	Iowa and North Carolina	Association of grain and dust exposures and chronic bronchitis amongst non-smoking farm women.
	Valery et.al. (2002)	Australia	Farm exposures, parental occupation and risk of Ewings Sarcoma in Australia (national case control study).
	Van Balen et.al. (2005)	Spain	Exposure to non-arsenic pesticides is associated with lymphoma among farmers in Spain.
	Voaklander et.al. (2006)	Alberta	Pain, medication and injury in older farmers.
	Waddell et.al. (2001)	USA	Relationship between the use of organophosphate pesticides and non-Hodgkin's Lymphoma. 748 cases of non-Hodgkin's lymphoma and 2236 population controls.
	Whyte (2002)	UK	Occupational exposure of poultry stockmen in current barn systems for egg production in the UK.
	Zheng et.al. (2001)	Four midwestern States USA	Risk of non-Hodgkin lymphoma from carbamate insecticide use among farmers. 985 white male subects and 2895 control subjects.
Cross-sectional Studies			
	Beseler (2006)	Colarado	The relationship between previous pesticide poisoning, depression and safety behaviours. Cross sectional survey of farmers and their spouses in eight counties in Northeastern Colarado.
	Booth (2000)	England	Nature and extent of stress in farming. Postal survey of farmers in the South West of England.
	Browning et al (2001)	Kentucky	Tractor Driving Among Kentucky Farm Youth –health and hazard surveillance project
	Carruth (2002)	Louisiana	Risk stressors for depressive symptoms among farm women in souteast Louisiana.
	Carruth et.al. (2002)	Texas and Louisiana	Non fatal injury among women on family farms. 1096 working farm women in Texas and Louisiana.
	Carruth et. al. (2006)	Texas and Louisiana	Exposure to harzadous work activities (tractor use) among farm women. 665 women in Texas and 657 women in Louisiana, 18 years and above.
	Carruth et. al. (2007)	USA	Farm noise exposure and noise induced hearing loss. Descriptive correlational study of 56 farmers and family members.
	Chattopadhyay et. al. (2007)		Respiratory problems among grain storage depot workers. 316 workers.
	Chatzl et.al. (2006)	Greece	Association of allergic rhinitis with pesticide use among grape farmers in Crete, Greece. 120 grape farmers, 100 controls.
	Chaudemanche et.al. (2003)	France	Respiratory status in dairy farmers in France (cross sectional and longitudinal) Cohort constituted in 1994.
	Cole HPM et. al. (2006)	Kentucky	Operator death from tractor overturns and ROPS. Telephone survey of 6,063 Kentucky farms
	Cooper et.al. (2005)	Texas	Substance use, work and injuries among migrant and nonmigrant youth in rural Texas. 10 867 participants.
	Danuser et.al. (2001)	Switzerland	Prevalence and risk factors of self reported respiratory symptoms among Swiss farmers compared to general population.
	Downs et.al. (2002)	Australia	Whether having lived on a farm as a child is associated with a lower risk of allergic diseases.

Eduard et.al. (2004)	Norway	Relationship between farm exposures and asthma. Survey of 2149 farmers in south-eastern Norway.
Firth , et.al. (2006)	New Zealand	Dust and noise exposures among farmers in Southland, New Zealand.
Firth et.al. (2001)	New Zealand	Health of farmers in Southland, 586 participants from 286 farms.
Firth et.al. (2007)	New Zealand	Stress in New Zealand farmers, cross sectional survey n=1015.
Gerberich et.al. (2001)	USA	Injuries among children and youth in farm households: regional rural injury study. 13 144 participants
Jones (2005)	USA	ATV related behaviours, exposures and injuries -farm youth and nonfarm youth. 652 youths in Arkansas.
Judd et al (2006)	Australia	Mental health disorders in farmers, Australia.
Kamel et.al. (2007)	USA	Neurological symptoms in licensed pesticide applicators. Cross sectional data from 18 782 Caucasian male licensed pesticide applicators (1993-1997).
Lindsay et.al. (2004)	Scotland	Incidence and nature of self reported injuries to farmers while tagging calves and clipping cattle. Cross sectional postal survey of 4495 farmers.
Lower, Egginton & Owen (2003)	Australia	Agricultural Motorcycle Injuries in Western Australia.
McBride, et al (2003)	New Zealand	Noise exposure and hearing loss in agriculture, farmers and farm workers in the southern region of New Zealand
Mariger et.al. (2007)	Virginia	Determining the effect of exposure to agricultural hazards on traumatic injuries, chronic illness and general health. Sample of 1650 farmers.
Mather & Lower (2001)	Australia	All injury in sheep farmers
Monso et.al. (2000)	Europe	Crop farming as a risk factor for respiratory symptoms of obstructive lung disease. Random samples from four European countries following a cross-sectional design. 4793 crop farmers, response rate 85.3%.
Monso , et.al. (2004)	Europe	Chronic obstructive pulmonary disease among never smoking animal farmers working inside confinement buildings. Cross sectional sample from four European countries.
Monso (2003)	California/Europe	Region related risk factors for respiratory symptoms. European 7,188; Californian 1 839 participants.
Palmer et.al. (2000)	UK	Prevalence and pattern of occupational exposure to hand transmitted vibration in Britain. 12 907 subjects.
Peden et.al. (2005)	Kentucky/Iowa	Depressive symptoms in adolescents living in rural America. Convenience sample of 299 14-18 year olds at five rural high schools.
Pilkington et.al. (2001)	UK	Epidemiological study of the relations between exposure to organophosphate pesticides and indices of chronic peripheral neuropathy and neuropsychological abnormalities in sheep farmers and dippers. 612 sheep dipping farmers, 53 farmers (no sheep dipping), 107 ceramic workers.
Radon et.al. (2001)	Europe	Risk of occupational airway disease; a comparison of airway symptoms predominate among different types of animal farmers compared with prevalence symptoms among the general population. 6156 randomly selected farmers in Denmark, Germany, Switzerland and Spain.
Rossignol (2003)	France	Primary osteoarthritis and occupations, national cross sectional survey of 10 412 symptomatic patients.
Sallmen et.al. (2006)	Finland	Fertility and exposure to solvents among families in agriculture. 2112 participants, women aged less than 40 years.
Samanic et.al. (2006)	Iowa and North Carolina	Cancer incidence among pesticide applicators exposed to dicamba. 41 969 applicators, 22,036 who had used dicamba.
Sanderson et.al. (2006)	Iowa	Tractor overturns in Iowa and rollover protective structures (ROPS) and seatbelts. Population based study in Keokuk Country, Iowa (Number of participants????).

	Sanne et.al. (2004)	??	Risk of anxiety and depression among farmers. 17 295 workers aged 40-49 years, including 917 farmers from the population based Hordaland Health Survey 1997-99.
	Simpson et.al. (2004)	Ontario	Associations between perceived psychological stress and farm injury among men and women in Ontario, Canada.
	Snyder et al (2003)	Nebraska	The relationship between agricultural environments and olfactory dysfunction
	Stallones (2002)	Colarado	Evaluation of the association between pesticides and depressive symptoms among population exposed to chemicals as a result of agricultural use. Cross sectional survey of farmers and their spouses in an eight county area in northeastern Colorado. 761 participants.
	Stallones (2006)	Colarado	Sleep patterns and risk of injury among adolescent farm residents. 262 youth, aged between 13-18 years randomly selected for a cross sectional survey.
	Van Maele-Fabry (2004)	International	Occurrence of prostate cancer in pesticide applicators and in other related occupational categories. Metaanalysis off 22 studies identified on Medline (1966-2003).
	Talini et.al. (2003)	Tuscany	Risk factors for chronic respiratory disorders in a sample of farmers in middle Italy. 461 agricultural workers from two areas in Tuscany.
Descriptive Studies			
Analyses of routine data			
	Adekoya (2003)	USA	Trends in childhood drowning on US farms 1986-1997. Mortality data files from the National Center for Health Statistics; 1986-1997.
	Alexe et.al. (2003)	Greece	Occupational and leisure farm injuries in Greece. Emergency Department Injury Surveillance System.
	Arif et.al. (2002)	USA	Prevalence and risk factors of work related asthma by industry among US workers (1984-94).
	Athanasiov et. al.	Australia	Auger related compensated injuries. Queensland, Australia.
	Atrubin et.al. (2005)	Ohio	Self reported symptoms of neurotoxicity and agricultural injuries among Ohio cash-grain farmers. Reanalysis of previously published case control study of cash grain farmers in Ohio.
	Beer (2005)	USA	Analysis of factors contributing to 674 agricultural driveline-related injuries and fatalities between 1970-2003.
	Beer (2007)	USA	Driveline related incidents resulting in fatal and non-fatal injury among US children and adolescents 1970-2004. Database of driveline related injuries, Purdue University.
	Bugeja & Franklin (2005)	Australia	Dam drowning deaths in 0.5 year olds. Victoria.
	Bentley & Tappin	New Zealand	Analysis of slips, trips and falls in Ne wZealand dairy farming
	Clary (2003)	California	Pancreatic Cancer mortality and organochlorine pesticide exposure in California 1989-1996
	Dimich-Ward et.al. (2004)	Canada	Gender differences in the occurrence of farm related injuries. 1990-1996.
	Feyer et.al. (2001)	USA/Australia/NZ	Comparison of work related fatal injuries in the United States, Australia and New Zealand.
	Franklin, et al (2001)	Australia	Farm work related fatalities, Australia.
	Franklin, et.al. (2004)	Australia	Fall related fatalities, hospital admissions, emergency presentations, compensation claims in farmers and farm workers. Multiple data bases.J177
	Goldcamp et.al. (2006)	USA	Nonfatal All-Terrain Vehicle related Injuries to Youth on farms in the United States. Analysis of the National Institute for Occupational Safety and Health and the US Department of Agriculture 2001 Childhood Agricultural Injury Survey.
	Goldcamp , Meyers (2004)	USA	Youth farm fatalities 1995-2000, comparison by age groups. Death certificate data from 1995-2000 collected by NIOSH from 50 state vital statistics registries.

Gregoire (2002)	United Kingdom	Suicide rates among farmers and farm workers in the United Kingdom.
Hard & Gerberich (2002)	USA	Traumatic injuries in agriculture. Census of Fatal Occupational Injuries; Traumatic Injury Surveillance of Farmers; Regional Rural Injury Studies I and II (data sources).
Hard (2006)	USA	Fatal work related injuries in agricultural production among youth in the United States. Census of Fatal Occupational Injuries (CCFOI) developed by the Bureau of Labor Statistics (BLS).
Hendricks et al (2004)	USA	On farm falls among youth less than twenty years old in the United States.
Horsburgh et.al. (2001)	New Zealand	Fatal work related injuries in agricultural production and services to agricultural sectors of New Zealand, 1985-1994.
Hubler (2002)	Pennsylvania	Incidence and nature of farm related injuries among Pennsylvania Amish children: implications for education.
Kingman et al (2001)	USA	Fatal entrapments in on-farm grain storage bins, 1966-1998.
Lee et.al. (2002)	USA	Proportionate mortality of crop and livestock farmers in the United States, 1984-1993. Analysis of occupation and industry coded US death certificate data from 26 states 1984-1993.
Liller & Lehtola (2000)	Florida	Analysis of injury on Florida farms 1989-1998. Review of death certificates 0-18 years +.
Lilly et.al. (2004)	New Zealand	Child work related injury study 1985-1998.
Little et.al. (2003)	USA	Farm children and risk of injury (1994-2001).
Lower et al (2002)	Canada	Agricultural machinery injuries in Ontario 1985-1996 a comparison of males and females
Page & Fragar (2002)	Australia	Suicide among farm managers and agricultural labourers in Australia 1988-1997.
McClure et al (2005)	Minnesota	Farm related amputations in children
McDuffie et.al. (2007)	Canada	Host factors, occupation and testicular cancer in Saskatchewan. 1979-2002.
McDonald et.al. (2005)	UK	Incidence by occupation and industry of acute work related respiratory diseases in the UK, 1992-2001. (data from national surveillance schemes).
Meirers (2001)	?	January 1988-December 1999, analysis of childhood farm injuries referred to a trauma centre. 45 children under 19 years of age identified.
Mitchell et.al. (2001)	Australia	Fatalities in children less than 15 years old on farms. Australia.
Mitchell et.al. (2002)	Australia	Fatalities in 15-24 yr & > 55 yr olds on farms. Coronial file review.
t'Mannetje et.al. (2007)	New Zealand	High risk occupations for non-Hodgkin's lymphoma in New Zealand - cancer registry; 291 incident cases and 471 population controls. 2003-2004.
Marlenga et.al. (2006)	USA	Policy outcome evaluation of policy aiming to reduce youth tractor crashes on public roads. A review of a retrospective case series. 146 tractor crash cases.
Mason (2002)	New York	Child agricultural injuries in New York State. Analysis of risk factors. The New York Community Partners for Healthy Farming (CPHF) surveillance.
Myers (2001)	USA	Fatal on farm injuries among youth 16-19 years. Data from the Vital Statistics Mortality (VSM) and the National Traumatic Occupational Fatalities (NTOF) surveillance systems.
Page et.al. (2007)	Australia	Rural suicide among young Australian adults 1979-2003.
Pickett et al (2005)	Canada and the USA	Pediatric farm injuries involving non-working children injured by a farm work hazard. Data: fatal, hospitalized and restricted activity farm injuries from Canada and the United States.
Pickett et.al. (2007)	Canada and the USA	Pediatric fall injuries in agricultural settings. Retrospective case series from registries in Canada and the United States.
Reynolds et.al. (2005)	California	Residential proximity to agricultural pesticide use and incidence of breast cancer in California 1988-1997.
Reynolds et.al. (2005b)	California	Agricultural pesticide and lymphoproliferative childhood cancer in California.

	Rissanen (2003)	Finland	Fatal farm injuries in Finland between 1988 - 2000.
	Rautianen(2002)	USA	Mortality and morbidity in agriculture in the United States.
	Rodvall et.al. (2003)	Sweden	Cancer risk in offspring of male pesticide applications in agriculture in Sweden. 51 cases.
	Rossignol et.al. (2005)	France	Primary osteoarthritis of hip, knee and hand in relation to occupational exposure. N=??
	Simkin et.al. (2003)	England and Wales	Seasonality of suicide in England and Wales. 1982-1999.
	Sjogren et.al. (2003)	Sweden	Ischaemic heart disease among livestock and agricultural workers.
	Saar et.al. (2006)	Canada	Farm injuries and fatalities in British Columbia, 1990-2000.
	Schwab et al (2000)	USA	An assessment of the condition of Iowa Augers, Auger related injuries and perceptions of these injuries
	Stark et.al. (2006)	Scotland	Suicide in farmers in Scotland. 1981-1999.
	Shaults et.al. (2005)	USA	All terrain-vehicle-related nonfatal injuries among young riders, 2001-2003.
	Sosnowska (2007)	Poland	Incidence and nature of farm related injuries among children (6-15 years) during a ten year period in Poland. Farm Insurance Fund (registers farm related injuries).
	Svec et.al. (2005)	USA	Risk of lymphatic or hematopoietic cancer mortality with occupational exposure to animals or the public. 1984-1988 in 24 US states, death certificate data. N=68 598, 912 615 controls randomly selected.
	Terzioglu (2004)	Anatolia	Injuries to children's hands caused by engine belts on agricultural machines
	Thelin (2002)	Sweden	Fatal accidents in Swedish farming and forestry, 1988-1997.
	Thorns et.al. (2008)	New Zealand	Epidemiology of noise-induced hearing loss in New Zealand.
	Todd et al (2005)	West Central Illinois	Pediatric ATV Injuries
	Thornley et.al. (2002)	New Zealand	Changing epidemiology of human leptospirosis in New Zealand. Surveillance and disease notification data.
Case Series			
	Alderate et.al. (2000)	California	Lifetime prevalence of and risk factors for psychiatric disorders among Mexican migrant farm workers in California. 18-59 year olds, 1001 participants.
	Brison et.al. (2006)	Canada	Fatal agricultural injuries in preschool children: risks, injury patterns and strategies for prevention. National case series assembled retrospectively for the years 1990-2001
	Davies & Franklin (2006)	Australia	Horse and motorbike related injuries, Australia.
	DeArmond et.al. (2006)	Colorado	Depression and somatic symptoms within the farming community. 709 participants.
	Depczynski et.al. (2005)	Australia	Farm noise emissions during common agricultural activities. Farm visits to 48 agricultural establishments.
	Eduard et.al. (2004)	Norway	Farming exposures- cause or prevention of asthma. Adult Norwegian farmers (n=2169).
	Franklin & Davies (2003)	Australia	Farm related injury, hospital presenting.
	Hagel et al (2004)	USA	Effect of age on hospitalized machine related farm injuries amongst Saskatchewan farm population.
	Hendricks (2001)	USA	Non-fatal animal related injuries to youth on farms in the USA - 1998. Survey of 26,000 households
	Judd et. al. (2006)	Australia	Mental health disorders in farmers. Australia.
	Smith et.al. (2004)	USA	Pediatric farm-related injuries, a series of 96 hospitalised patients.
	Windsor et al (2005)	Australia	Injury caused by self inoculation with sheep vaccine. Australia.
Prevalence Surveys			
	Chapman et al (2003)	Wisconsin	Musculoskeletal discomfort, injuries and tasks accomplished by children and adolescents in fresh market fruit production
	Hendricks (2005)	USA	Household youth on minority operated farms in the United States, exposures to injury from work, horses, ATVs and tractors

	Judd et.al. (2006)	Australia	Suicide and Australian farmers
	Kimbell-Dunn et.al. (2001)	New Zealand	Work-related respiratory symptoms in New Zealand farmers. N=1706.
	Lamprecht et.al. (2007)	USA	Farming and the prevalence of non-reversible airways obstruction. A population based study; gender stratified population based sample of 2,200 adults aged forty years and over.
	Lee et.al. (2005)	USA	Agricultural pesticide use and risk of glioma in Nebraska. 251 cases and 498 controls.
	McCurdy et.al. (2004)	California	Non-fatal occupational injury among Californian farm operators. Population based telephone survey 1947 participants; 80.4% response rate)
	Melbostad (2001)	Norway	Organic dust-related respiratory and eye irritation in Norwegian farmers. Survey of 8,482 farmers and spouses.
	Park et.al. (2001)	Iowa	Risk factors for back pain among male farmers. 287 Iowa male farmers 1992-1994 mail survey.
	Radon et.al. (2000)	German	Lung function and work-related exposure in pig farmers with respiratory symptoms. 100 swine producers with respiratory symptoms.
	Radon et.al. (2007)	German	Environmental exposure to confined animal feeding operations and respiratory health of neighbours. Survey of four German towns (2002-2004) with a high density of confined animal feeding operations.
	Radon &Winter (2003)	South Germany	Prevalence of respiratory symptoms in sheep breeders. 325 surveyed in two regions of South Germany.
	Reed & et al (2006)	Kentucky, Iowa, Missisippi	Protective equipment and risk exposures among adolescents. Survey of adolescent high school students.
	Rosecrance& Merlino (2006)	Southeast Kansas	Prevalence of lower back pain and musculoskeletal symptoms among Kansas farmers. Postal survey 499 active farmers.
	Schenker et.al. (2005)	California	Agricultural dust exposure and respiratory symptoms. Population based survey of 1 947 California farmers.
	Solomon et.al. (2007)	UK	Non-fatal occupational injuries in British Agriculture. Postal survey from men born between 1933-1977. 10765 respondents.
	Solomon et.al. (2007)	UK	Neuropsychiatric symptoms in past users of sheep dip and other pesticides.
	Smit et.al. (2006)	Netherlands	Hay fever and asthma symptoms in conventional and organic farmers in The Netherlands. 1205 conventional farmers; 593 organic farmers.
	Spengler et.al. (2004)	Kentucky	Sleep deprivation and injuries in part-time Kentucky farmers. 1004 part time farmers (1994-1995).
	Tahmaz & Cherie (2003)	UK	Chronic fatigue and organophosphate pesticides in sheep farming: a retrospective study.
	Wilkinson & Field (2005)	USA	Measurement of Operator Exposure to Power Take Off Driven Augers.
Onsite observational			
	Allread et al (2004)	Mid West USA	Physical demands and low-back injury risk among children and adolescents
	Earle-Richardson G et al (2004)	New York State	Ergonomic analysis of apple harvest work using a posture-activities-tools-handling (PATH) Work sampling approach
	Eduard et.al. (2001)	Europe	Short term exposure to airborne microbial agents during farm work, exposure response relations with eye and respiratory symptoms. Onsite medical screening of 106 farmers and their spouses.
	Goglia et.al. (2006)		Influence of hand-transmitted vibrations from handles of a single axle tractor on operators health.
	Milosavljevic et.al. (2005)	New Zealand	Influence of occupation on lumbar sagittal motion and posture. 64 shearers and 64 non-shearers; matched by age and anthropometry.
	Milosavljevic et.al. (2004)	New Zealand	Influence of a back support harness on spinal forces during sheep shearing. 26-51 yrs, 12 professional shearers.

Medical Screenings

Depczynski et al (2005)	Australia	Farm noise emissions during common agricultural activities
Milosavljevic et.al. (2005)	New Zealand	The influence of occupation on lumbar sagittal motion and posture, shearers and non-shearers.
Radon et.al. (2001)	Denmark/Switzerland	Exposure assessment and lung function in pig and poultry farmers. 40 pig farmers in Denmark and 36 Poultry farmers in Switzerland.
Skorska, et.al. (2003)	Europe	Health effects of inhalation exposure to organic dust in hops farmers. 23 Hops farmers and 50 urban dwellers.
Solecki (2003)	Poland	Occupational hearing loss risk among private farmers. 31 family farms.
Vermeulen et.al. (2005)	Iowa	Application versus exposure - pesticide exposure. 30 corn farmers and 10 non farming controls. Urine samples.
Wickens et.al. (2002)	New Zealand	Farm residence and exposures and the risk of allergic diseases in New Zealand children. (skin prick and survey of parents).

Reviews

Cherry & Gilmore (2007)		Children's health in the rural environment (North America)
Coggon (2002)		Work with pesticides and orgnanophosphate sheep dips.
Colemont & Van den Broucke (2006)		Psychological determinants of behaviours leading to occupational injuries and diseases in agriculture
Davis & Kotowski (2007)		Ergonomic risk for musculoskeletal disorders in the United States agricultural sector.
DeMuri (2000)		Farm injuries in children.
Fraser et.al. (2005)		Farming and mental health problems and mental illness. Overview of literature in the UK, Europe, Australia, Canada and the United States.
Fuchs et.al. (2007)		Health risks related to crop farming in Europe.
Hankes (2004)		Risk of adverse reproductive and developmental disorders due to occupational pesticide exposure - review of epidemiological evidence.
Iversen et.al. (2000)		Human health effects of dust exposure in animal confinement buildings.
Jaga (2007)	International	The interrelation between organophosphate toxicity and the epidemiology of depression and suicide.
Jurewicz & Hanke (2006)	Europe and the USA	Exposure to Pesticides and Childhood cancer risk. Review of epidemiological studies 1999-2007.
Kirkhorn & Schenker		Current health effects of agricultural work
Kouiminitzis et.al. (2007)		Health effects of livestock farming in Europe.
Linaker & Smedley (2002)		Respiratory illness in agricultural workers.
London et.al. (2005)		Suicide and exposure to organophosphate insecticides.
McCullagh (2002)		Preservation of hearing among agricultural workers
McCurdy & Carroll (2000)		Agricultural Injury
Omland (2002)		Exposure and respiratory health in farming in temperate zones.
Perry (2003)		Children's agricultural health: traumatic injuries and hazardous inorganic exposures.
Perry & May (2005)		Noise and chemical induced hearing loss: farm youth.
Reed & Claunch (2000)		Nonfatal farm injury incidence and disability to children, systematic review.
Shutske & Jenkins (2002)	USA	Review of the impact of biotechnology on agricultural worker safety and health
Solomon (2002)	Britain	Accidental injuries in agriculture in the UK
Spiewak (2001)		Pesticides as a cause of occupational skin disease in farmers.
Spurzem (2002)		Agricultural lung disease.

Van Maeie-Fabry et.al. (2007)	International	A systematic review and metaanalysis of published studies examining the association between myeloid leukemia's and occupational pesticide exposure.
Johnstone et.al. (2007)	Australia	Organophosphate pesticide exposure in agricultural workers. Human exposure and risk assessment.

Grey Literature - Australia and New Zealand

Miller & Fragar (2006)	Australia	Cases of farm tractor related injury and fatality.
Miller & Fragar et.al. (2006)	Australia	Post hole and Post driver injuries
Basham M (2006)	New Zealand	ABC's of ATV's. Factors implicated in child deaths and injuries involving all terrain vehicles on New Zealand farms

Appendix B

Risk factors for work related farm injury: summary of the epidemiological evidence

Study design	Participants	Exposure	Outcome	Confounders considered	Results
Cohort					
Bancej CA (2000)	n=1 765 full time family operated farms. Ontario	age, gender, location, causes of injury	All injury		Injury patterns and risk factors across age groups were heterogeneous. However, falls and machinery consistently ranked in the top three for all age groups.
Carlson KF et.al. (2005)	3 765 households	age, gender, location, causes of injury	Tractor-related injury	None considered	Over-all injury rate 9.6 events/1000 persons/year. Increased risk for males with prior injury experience. Variance by age, gender and prior injury. High risk group: 35-44 age group.
Flower KH et al (2006)	n=21 360 children, Iowa and North Carolina.	farm type, family characteristics, age, gender.	Mortality	None considered	162 deaths in Iowa and 26 deaths in North Carolina in children aged 0.19 years. Deaths from unintentional injury were not increased, but excess agricultural machinery mortality was observed in Iowa. Maternal age less than 25yrs and having more than two children in the family was associated with increased risk of agricultural machine-related mortality.

Gomez M et al (2003)	n=1706, New York counties	age, gender, location, occupational status	Musculoskeletal conditions	None considered	Joint pain over the last 12 months: lower back 41`%; neck/shoulders 35%; knees 29%, hands/wrists 28% and hips 15%. Logistic regression modelling identified significant risk factors for joint problems: older age, femal, bein the owner/operator increased the risk of neck/shoulder problems. Tractor work was associated with problems in all five joint areas and milking was associated with knee problems. Ergonomic improvements to tractors and milking facilities are needed.
Merchant JA et al (2002) South-eastern Iowa, agricultural county	South Eastern Iowa	age, gender, location, causes of injury	All injury	None considered	Males: had higher injury rates, more likely to be obese and overweight, higher rates of hearing loss and less likely to see a medical practitioner. Women had poorer emotional health and higher rates of depressive symptoms.
Parker HS et.al. (2001)	n= 290 principal farm operators. Iowa.	age, gender, location, causes of injury, season (fall)	All injury	None considered	Depressive symptoms and number of hours with animals associated with incidence of farmwork related injuries.

Voaklander DC (2006)	Alberta, older male farmers	age, gender, location, causes of injury	All injury	None considered	Distraction from pain or co-morbidity might play an important role in the etiology of injuries.
Toren AO et al (2002)	National survey of properties larger than 10 ha, Sweden.	age, gender, location, tractor, production type	Self reported low back and hip symptoms	None considered	Annual exposure to tractor driving and its distribution across different work practices. Annual exposure hours: 472 hours. While ploughing was the most time consuming operation it had no influence on the risk of low back pain or hip pain.
Solecki L (2003)	n= 31 family farms, Poland.	males, age, noise exposure.	Risk of hearing impediment	None considered	Results confirm that noise present in the working environment of private farmers creates significant risk for the organ of hearing.

Shipp E et al (2007)	n=2536 students. Texas.	age, gender, location, ethnicity, work-relatedness, non-work.	Self reported back pain, prevalence and risk factors, back pain resulting in 4+ hours of time lost; medical care; or pain lasting more than 1+ week).	None considered	Severe back pain reported by 15.7% of farmworkers and 12.4% non-farm workers. A multiple logistic regression for farmworkers showed significantly increased adjusted odds ratios for severe back pain amongst female (4.59); those with prior back injury (9.04); those feeling tense, stressed, or anxious sometimes/often (4.11); those lifting or carrying heavy objects while not at work (2.98); currrent tabbacco use (2.79); those with 6+ years involved in migrant farm work (5.02); working with/around knives (3.87); working on corn crops.
Sprince et.al. (2003)	6 999 farmers in Iowa, identified 431 with injuries, 473 controls with no injury in previous year	age, gender, location, causes of injury, working hours, livestock, education, medication use, wearing a hearing aid.	All injury	None considered	Significant associations between farm work-related injury and: weekly farming hours (>=50hours/week); presence of large livestock; education beyond high school; regular medication use; wearing a hearing aid; and younger age.

Sprince et.al. (2003b)	n= 6999 farmers in Iowa, subset of 79 farmers with fall related injury. 473 controls with no injury in past year.	age, gender, location, work relatedness,	Fall related injury	None considered	Significant associations between fall-related farm injury: and age between 40-64 years; doctor-diagnosed arthritis/rheumatism, hearing difficulties; and taking regular medications. Aging and health impairments (such as arthritis or hearing difficulties) are risk factors for fall-related injuries.
Sprince NZ et.al. (2007)	n= 6999 farmers in Iowa. Identified subset of 49 male farmers, compared with 465 uninjured male farmer controls.	age, gender, location, work relatedness,	Low back injury	Age, education (younger age group more educated than older).	Multivariable modelling identified four risk factors significantly associated with low back injury 1) age less than 45 years 2)doctor diagnosed asthma 3)education beyond high school 4) hearing difficulties. Asthma may be a more specific risk factor for low back injury.
Sprince et.al. (2003)	n=6999 farmers in Iowa. Identified 116 farmers with large livestock who had animal related injury requiring medical intervention in last year. 342 farmer controls with large livestock who had not been injured in last year.	age, gender, location, work relatedness,	Large livestock related injury	Age, education	Multiple logistic regression analysis showed significant associations between animal-related injury and the use of a hearing aid; doctors diagnosed arthritis or rheumatism; education beyond high school and younger age.

Sprince et.al. (2002)	n=6999 farmers in Iowa. Identified 205 farmers who had machinery-related injuries requiring medical assistance in the last year. Control 473 farmers with no injury in last year.	age, gender, location, work relatedness, machines.	Machinery related injury		Multiple logistic regression analysis showed significant associations between machinery related injury and :hours per week spent on farmwork, fewer years of farming experience, wearing a hearing aid and a high CAGE score indicating problem drinking.
Hartmann E et.al. (2006)	89 sick leave claim for neck/shoulder/upper extremity trouble and 198 for back trouble. 816 controls who did not file claims in this period	age, gender, location, work relatedness,	musculoskeletal disorders	None considered	Multivariate analysis showed that risk factors increased with age: for back,neck, shoulder, upper extremity trouble; increased with body mass index >27; smoking, former pain; tractor driving >1000hours/year; and high work pace and workload. Neck, shoulder and upper extremity problems associated with pig, mushroom and dairy/pig farming, age, smoking, former pain also contributing.

Holmberg ST et.al. (2004)	778 participants with x-ray verified osteoarthritis in the femorotibial joint; 695 controls.	age, gender, work relatedness (range of occupations including farming)	Knee osteoarthritis	None considered	89% response rate. Mean age of participants was 63 years, 43% were male and 57% female. Multiple logistic regression analysis showed that farm work was not related to an increased risk for men. However, women who had worked for 11-30 years in farming tended to have an increased risk. Excess weight, heredity and previous knee injury were strong risk factors; whereas smoking showed a negative relationship to knee osteoarthritis.

Cross-Sectional Studies

Acsota MS et.al. (2007)	4914 participants; School students (9^{th}-graders)in South Texas	age, gender, work relatedness, health risk behaviours	Work-related injury	Confounders considered	An ARS score was developed based on health risk behaviours. Mean ARS scores were significantly higher ($p<0.05$) for both male and female adolescents who reported a work-related injury compared to nonworking adolescents; and for males who had done migrant farm work compared to all other males.Statistically significant association between ARS and non-farm work related injury, but not between ARS and farmwork related injury. Farmworkers with high ARS were more likely to report non-farmwork work related injuries.

Browning et al (2001)	N=1,189 1994-1995	Children	Tractor related		Operating tractors on public roads without ROPS with extra riders remains common amongst youth in Kentucky
Carruth AK et.al. (2002)	n=1096 farm women in Texas and Louisanna.	age, gender, work relatedness	Work related injury	None considered	Factors predictive of increased risk of injury by mulitiple logistic regression analysis included: large animal farm type, greater time committment, recurrent or persistent back conditions or weakness in last 12 months; hauling goods to market; driving a tractor for more than 52 days a year

Carruth AK et.al. (2006)	n=665 women in Texas and 657 women in Louisianna; 18years +; working on family farms. Of which 577 (43.6%) reported driving tractors at least one day a year. This subsample informed this study.	age, gender, work relatedness	Work-related injury, tractor usage	None considered	Tractor knowledge poor, husband's primary source of knowledge about tractor driving, engaged in a wide range of farm work with tractors and less likely to drive a tractor with ROPS or enclosed if driving less than 12 days a year.
Carruth A et.al. (2007)	Convenience sample of 56 farmers and family members recruited from community based agricultural event. Texas and Louisiana.	age, gender, work relatedness, recreational activities	Noise-induced hearing loss	None considered	80.4% of participants had a hearing impediment. Fewer than 10 reported wearing ear protection during work or recreational activities. Multiple regression analysis showed significant associations between high frequency hearing loss in the left ear; the attitude that wearing hearing protection prevents others from getting one's attention. Self reported description of hearing loss (in the left ear) significantly predicted hearing handicap.

Cole HP et.al. (2006)	n= 6063 Kentucky farms; 551(9.1%) reported tractor overturns.	age, gender, work relatedness,	Tractor overturn injuries	None considered	Injury outcomes for 443 overturns of non-ROPS tractors and 89 ROPS tractors were: no or minor injury (non ROPS 70.43%; ROPS 82.02%); outpatient treatment (non-ROPS 21.90%; ROPS 9.00%), hospital admission (non-ROPS 15.35%; ROPS 3.37%; temporary disability (non-ROPS 13.54%; ROPS 14.61%); permanent disability (non-ROPS 3.16%; ROPS 0.00%); and death (non-ROPS 5.42%;ROPS 1.12%). (% total more than 100 as some patients treated as outpatients were subsequently hospitalised, disabled or died). Probability of death from overturn of a non-ROPS tractor (0.08) is five times smaller than the NIOSH estimate of 0.40.
Cooper SP (2005)	7302 middle and 3565 high school students. Migrant students 5% of total.	age, gender, work-relatedness and migrant status	Work-related injury; substance use	None considered	Migrant students more likely to report frequent substance use, more likely to work for pay on weekday mornings before school and more likely to have been injured at work.

Firth H et al (2006)	Subsample of total 586 participa+B21nts, New Zealand.	farm buildings, work relatedness	Noise exposure inhalable dust exposure (hearing, respiratory conditions)	None considered	Median inhalable dust levels for arable farmers was 1.7mg/m3 with 0.7mg/m3 for sheep farmers (NZ standard 10mg/m3). Total daily noise exposure levels were 86.8 dB (A) for sheep farmers, and 85.7 dB(A) for mixed farmers (NZ standard 85 dB[A]. Noise is an important hazard for NZ farmers, dust less so based on inhaleable levels , levels were low due to the nature of farming in NZ where outdoor pastural farming is the norm.
Jones CB (2005)	652 youths in agricultural training programmes throughout the state of Arkansas	age, gender, work relatedness, location	ATV behaviours, exposures and injuries, non-farm youth compared to farm youth.	None considered	60% of students had operated ATVs within the past month. Farm youth were more likely to be white, male, to own a 3 wheel ATV and to ride more often with a single rider. Risk factors: frequency of use and number of people on the ATV.

Lindsay SS et.al. (2004)	4495 farmers with beef or dairy cattle in Scotland.	age, gender, work relatedness, diary or beef cattle, location	All injuries relating to dairy and beef cattle	None considered	54% response rate (2439) and 1341 injuries reported by 591 (24%) of respondents. Tagging injuries reported by 297 (12%) of respondents; bruising the most common injury; lacerations (3%) and fractures (3%). 20% of those with tagging related injuries lost time from work, median of 3 days away from work. 418 (17%) reported clipping related injuries; most common was brusing; lacerations (6%); fractures (7%) 23% of those with clipping related injuries lost time from work - four days median. Tagging injuries most commonly affected lower limbs and trunk, while clipping injuries affected the upper limbs. Tagging injuries most commonly when working alone, in an open field and with a vehicle nearby. Clipping injuries were associated with working alone, with beef cattle and with younger age. Tagging calves and clipping cattle prior to slaughter is associated with a significant risk of injury.

Lower et.al. (2003)	n=326 High School Students, Western Australia.	Agricultural Motor-cycle use.	Most recent injury	Components of the model adjusted for each other.	At greater risk of injury if self taught OR 2.13 (0.99-4.76) cf. Taught by adult, maximum speed 101 +km OR 4.53 (1.33-15.40) and wearing a helmet "sometimes" OR 4.10 (1.26-13.36).
McBride D. (2003)	n=586 workers, New Zealand	Age, tractors without cabs, working with metal.	Hearing loss	None considered	Noise on a subsample of farms (60) lay in a range between 84.8 to 86.8 dB(A) and hearing losses were consistent with this level of exposure. Age, driving tractors without cabs, working with metal were important risk factors. Reported compliance of hearing protection higher than that observed. Majority of farmers have moderate risk of hearing loss, minority have a risk of significant hearing loss.
Mather & Lower (2001)	n=506 All farm population	Commodity type, agent of injury, farm activity	Self-reported injury preceding two years.	None considered	Higher injury rates reported in sheep sector, with vehicles, with hand tools and during livestock management/handling.

Palmer KT et al (2000)	n=22 194 men and women aged 16-64yrs. England, Scotland and Wales	hand transmitted vibration	National survey by occupation and industry	None considered	Industries where high A(8)>5ms-2rms) most often arose in construction, motor repair, manufacture of basic metals and agriculture. Men most at risk.
Sanderson W et al (2006)	Iowa	age, gender, tractors, location, work relatedness, attitudes	All-injury, presence of ROPS	None considered	Participants owned on average 3.1 tractors with average age of tractor 27 years. Only 39% of the 665 tractors had ROPS. ROPS equipped tractors were more common on large farms and with households with a higher income. Only 4% of the farmers reported having seatbelts. 120-130 deaths/year in the US associated with tractor overturns.
Simpson KS et al (2004)	Ontario,	age, gender, work-relatedness	stress and farm injuries		The risk of farm injury was increased with the level of stress. Risks more pronounced among women who did work off the farm.

Stallones LB et al (2006)	n=262 youth (13-18 yrs) in Colorado	age, gender, sleep patterns, residence	Self reported injury in the preceding year	Multivariate modelling - controlled for other variables.	Univariate analysis to describe relationships of study variables with injuries. Multivariate modelling done to assess sleep patterns that were associated with injuries controlling for other variables. Sleep patterns associated with increased risk of injuries ($p<0.05$) included: oversleeping and having been late for class; falling asleep in afternoon classes; ever being up past 3am; sleeping less than an average of 9.25 hours per night on weekends and on school nights and weekends combined; and sleeping less than average of 8.5 hours on weekends and on school nights and weekends combined. Sleep patterns signficantly associated with occurrence of injuries.

Descriptive studies: Analyses of routine data					
Alexe DP et al (2003)	n=4 326 unintentional farm injuries. Emergency Department Injury Surveillance System, Greece	age, gender, environment, injury	Self-reported injury	None considered	Falls, cuts, piercings, machinery related, head injuries, dislocations, sprains, insect and snake bites, vehicle injuries. Distinct patterns of injury: older women (lower-limb fractures); young individuals (non-traffic vehicle related injuries); migrant workers (cutting and piercing from instruments, falls from high level and insect and snake bites)
Beer SR et al (2007)	n=151 (under 18 years). Data base Purdue University. USA.	age, gender, environment, season, machine, injury from driveline	All injury from drive-line related incidents	None considered	Drive-line related injury for youth under 18 years between 1970-2004. This age group make up 1 in 4 of all documented agricultural driveline incidents. Serious injuries: amputation (50% of cases), spinal cord injuries and compound bone fractures. Trend in documented cases is declining, with no fatalities in 2004. Male youth - 13 years - highest frequency of incidents, over 50% of all cases occurred to youth 12-17. Most incidents occurred

					in Fall. Augers, elevators and conveyors machines most frequently identified.
Beer SR et al (2007)	n=674. Data base Purdue University, USA.	age, gender, environment, season, machines, injury from driveline	Drive-line related incidents	None considered	Increases in drive line related injury between 1970-1980s, decreased in the 1990s and into the 2000s. 11-15 year olds had the highest frequency of cases, incidences happened more often in Fall; augers, elevators, conveyers were the type of machines most commonly involved.
Bentley & Tappin (2004)	N=475 2000-2002	Slips, trips and falls Age, gender, geographic location Activity preceding event	Dairy farming		STF's more common in the Waikato region, during periods of heavy workload, in older age groups, and in 28% of cases in females. Slips the most common fall initiating event. Injuries most commonly on concrete, in the cowshed, in the yard,

					on steps or when dismounting avehicle.
Bugeja & Franklin (2005)	n=27 children 0-5 yrs	Dams, age, day, gender, season, dam location, supervision, barrier	Fatal drowning in dams	None considered	Fatalities predominantly in spring/summer, weekends, males < 24 months old, dams within 300m of home, parental property, dams with inadequate fencing.
Davies and Franklin (2006)	n=148 horse and motorbike related injuries presenting to one hospital. Australia	age, gender, work-relatedness, admission to hospital, work activity.	Hospital presenting injury	None considered	Horse related injuries predominantly in females, while mustering, riding for leisure or work and older age if male. Motorcycle injuries predominantly in males, 2wd while riding for leisure, 4wd more likely to be admitted to hospital.
Dimich-Ward H (2004)	n=726. National surveillance data, Canada.	Age,gender, machinery, hospitalisation, fatality, animal related	Gender differences	None considered	More males injured (665 males, 61 females)- regardless of how the injury occurred, but particularly when farm machinery was involved. Fatal injuries: roll over (32%) for males and run-over (45%) for females. More males over the age of 60 injured.

Feyer AM et al (2001)	15-84 years, mortality data files, New Zealand.	Work-relatedness, age, gender, occupation, industry	Work-related fatal injury 1985-1994.	Changes in occupation and industry mix.	Rate of work-related fatal injury in New Zealand was 5.03/100 000 workers per year between 1985-1994. Elevated rates amongst: older workers, male workers, self-employed workers and particular occupational groups: agricultural, helicopter pilots, forestry, fishery had the highest rates. Farmers, foresters, and fishery workers accounted for 40% of the deaths.

Franklin et al (2001)	373 farm work-related fatalities, 1989-1992.	Work related fatalities	Fatality rate 20.6 per 100 000 workers per year. 5.3 per 10 000 agricultural establishments. Most at risk males, 40-49 year olds, meat cattle sector, farmers and farm managers, using farm vehicles and mobile farm machinery, while in transport for work purposes, maintenance, working with animals and working with crops, in a paddock or road/lane. Major mechanism vehicle related accidents, hit by moving objects and rollovers.

Franklin et al (2004)	Farmers and farm workers	Object fallen from, height of fall	Fall-related fatal injuries, hospitalisations	None considered	Fatalities predominantly from horses, machinery and vehicles, natural features and in stockyards. Hospitalisations involved falls from horses, machinery/vehicles, static falls from horses, ladders, trees and fences.
Goldcamp E et al (2006)	Youths on farms in USA (younger than 20 years)	ATV, age, gender, work relatedness, recreational, size of ATV	Nonfatal injuries - occupational non-occupational	None considered	Of an estimated 1.1 million youths living on farms in the US, 36% operated an ATV in 2001. Youths younger than 16 were more likely to have operated an ATV than a tractor. Estimated 2,246 non-fatal ATV related injuries occurred to youths younger than 20 yrs on US farms in 2001. 74% of these injuries occured to youths resident on the farm; males accounted for 69% of these injuries , majority of injuries were to youth 10-15 yrs. Most ATV injuries resulted from recreational use of ATVs (58%). Many occured to youths who were not wearing helmets or using ATVs that were larger than the recommended size for their age.

Goldcamp M et al (2004)	n=695 farm related youth fatalities. 50 state vital statistics registries. 1995-2000. USA	age, gender, work relatedness, recreational,	Fatal injuries, occupational non-occupational	None considered	Annual average farm fatality rate of 9.3 fatalities per 100,000 youths. Males account for 80% of the fatalities. Causes of death: machinery (25%); motor vehicle (17%); drowning (16%); suicide (8%); and homicide (6%). 45% of work related fatalities are to youth less than 16 yrs. Those less than 16yrs also account for 71% of non-work related fatalities.
Gregorie A (2002)	United Kingdom	farming practice, economic factors	intentional injury, suicide	None considered	Mental health in rural areas, acess issues. Farm workers and farmers in the UK account for the largest numbers of suicides in any occupational group.
Hard DI et al (2002)	US fatal and non-fatal injuries from national/regional surveillance systems	age, gender, work relatedness, machinery	fatal and non-fatal injury	None considered	1992-1998 25.8 deaths per 100 000 workers; 7.5 non-fatal injuries per 100 workers. Fatalities showed some decline in the 1980s, steady in the 1990s. Tractors leading cause of death mostly due to overturns. Older farmers at highest risk of farm fatalities. Traumatic injuries a major concern for youth living or working on farms.

Hard D I et al (2006)	n=310 work related deaths to youth <20yrs. Census of Fatal Occupational Injury	age, gender, work relatedness	Fatal injury	None considered	310 work related deaths for youth (<20yrs) from 1992-2002 in agriculture. Has been a general downward trend over this time period. Rates higher for young workers in agriculture than youth in other sectors by a factor of 3.6. 15 yr olds have the highest fatality rates, with crop production sector having a rate six times that of all 15 year old workers.
Hendricks et al (2004)	Non-fatal fall injury Fatal fall injury Youth	Age, work relatedness, Non-workrelatedness.	Fatal and non-fatal injury		Youth on farms (work and non-work related) are exposed to many different types of fall hazards. Extra riders on tractors and implements have resulted in many deaths.
Hubler CL (2002)	n=89 injuries of Amish children over a period of 5 months	age, gender, location, work relatedness	All injury.	None considered	Over a five month period a total of 89 injuries,k including 5 fatalities. Male children sustained 64 injuries, female children 25 injuries. Falls were the most common mechanism of injury, followed by incidents involving livestock. Both incidents most commonly resulted in orthopedic injury.

Holsburgh S et al (2001)	Fatal injury in agriculture. 1985-1994, 15-84 years. New Zealand. Coroner files.	work-relatedness, mechanism, age, gender	Fatal injury	None considered	Fatal injury rate, 1985-1994, for male agricultural workers 21.2/100 000, with injury deaths in the agricultural sector accounting for nearly a quarter of all work-related deaths in New Zealand. Those at higher risk included: older workers (65-84yrs). Most common mechanisms: machinery and motor vehicles, over turns being the most common event.
Kingman et al (2001)	N=391 cases of non-fatal and fatal entrapments in grain storage bins	Work relatedness and Non-work relatedness Age, gender	Fatal and non-fatal injury		Entrapments more common in corn producing states. Children and young people more commonly fatally entrapped in June. In 76% of the cases entrapment occurred during unloading activities.
Liller and Lehtola (2000)	Fatal injury, 1989-1998. Farms in Florida.	age, gender, location, work relatedness, mechanism	Fatal injury.	None considered	Children 0-17 years and adults 18 years and older. Total of 231 injury deaths over this period. 20 deaths were children and 211 deaths were adults. Leading cause of death was machinery for both children and adults. Adult males more likely to die on farms than adult females. However females are more

					likely to die as a result of homicide.
Lilly R et al (2004)	n=87 work-related fatalities, <15 years, 1985-1998.	Age ,location, work-relatedness	Fatal injury	None considered	The majority of children were fatally injured while a bystander to another person working. A third of all fatalities occurred within the agricultural industry. Between 1985-1994 children less than 15 years of age accounted for 46% of New Zealand's total workplace bystander deaths.

Little D et al (2003)	n=1832 pediatric trauma cases	age, location, mechanism	All injury	None considered	Of the 1832 pediatric trauma cases 94 were children with farm related injuries. Mean age was 10.75 years. Mean ISS was 7.38. Three children died. Four children wore protective equipment. 44% of injuries were in the summer, 31% in spring, and 55% on weekends. 39 minutes to presentation, 177 minutes before transfer to trauma centre. 72 children were admitted. LOS 0-28 days; mean 2.76 days. 28% required operations; 52% dislocations/fractures; 38% lacerations and avulsions, 31% concussions, 30% contusions and 14% burns. Mechanisms included: animals (41%); falls (34%); motor vehicles (28%); all terrain vehicles (20%); firearms (4%).
Locker et al (2002)	Fatal & Hospitalized machinery injuries	Males and females On farms between 1985-1996	Agricultural Machinery injury		Distribution of injuries by males and females were statistically different by age, production season and mechanism of injury. Gender specific injury patterns.

McClure et al (2005)	Limb amptutations	Children	Mechanism of injury Surgical data		Children who are operating machinery, bystander injuries. Issues: entanglement, lack of guards, children under 18 years should not be operating this machinery – recommendation.
Marlenga B et al (2006)	n=146 Tractor crashes. Wisconsin 1994-2003.	age, highways, tractors	Fatal and non-fatal injury	Tractor certification course did not cover the major factors contributing to youth tractor crashes on public roads.	146 tractor crashes involving operators < 16 years on highways. Evaluating effectiveness of state law change (Wisconsin ACT 455). No significant change in the number of youth tractor crashes; no reduction in the number of crashes where the youth operator designated at fault.

Mason (2002)	CE	n=164 injuries, 1-18 years, New York farms, CPHR surveillance program.	age, mechanism, environment	fatal and non-fatal injury	None considered	164 injuries, 29 of which were fatalities; 18 were disabling; 55% occurred while working. Leading injury mechanisms: tractor run-over (12); and overturns (11). Of those working 35% were under the "job appropriate age limits". Task loading square bales (100% 3), fieldwork with trailed implements (100% 3), feeding calves (100% 2) - most commonly involved young victims. Injuries involving non-powered wagons had the highest frequency of under-age victims (82% 9). Children in NY being assigned tasks that are developmentally inappropriate.

Meiers SB (2001)	Trauma centre referrals 1989-1998.	age, mechanism, outcomes, transportation time	fatal and non-fatal injury		45 children under 19 years injured. Mean age was 7.3 years, 14 of the 45 died. , Male to female ratio 2:1. 69% survived their injury. Mechanisms of injury: tractor (33%); animals (29%);other machinery (9%); falls (9%), burns (4%). 12 deaths involved tractors or machinery (84%). June to October prevalent period; and hours of 1pm - 6pm. 9 fatalities were supervised. Injuries included: orthopedic (56%); and neurologic (42%); and thoracoabdominal (22%). 13% had long term disability. 7 of the fatalities had solitary head injuries. Average transport time to rural hospital 1.5 hours, from hospital to trauma centre 2.3 hours. 2 died on route.
Mitchell et al (2001)	115 children <15 years old	Farm environment	Fatal Injury 1989-1992	None considered	Average of 29 deaths per year. Males more commonly injured than females, children < five years represent majority of injuries. Common location for injury, dams and bodies of water, agent water and mechanism drowning. Other agents tractors /utilities.

Mitchell et al (2002)	Young adults 15-24 years; Older adults aged 55 years and over. Australia. Administrative data set.	age, work relatedness, work sector, mechanisms	Fatal injury 1982-1984 1989-1992	None considered	Rates of work-related injuries higher in both age groups for agricultural work vs all industries for both 1982-1984 and 1989-1992. Rates for oldest age groups higher than all age rate for agriculture. Tractors common agent in older adults while motor vehicles and firearms for 15-24 years.
Myers JA (2001)	Fatal injury for youth 16-19 years of age in the United States.	age, work relatedness, recreational, mechanisms	Fatal injury on farms 1982-1994	None considered	550 on farm fatalities for youth 16-19 years; 40% of the onfarm deaths were occupational. Proportions of death attributable to work increased with age. Slight decrease in on farm non-occupational deaths in this period and dramatic decrease in on farm occupational deaths (12.0 deaths/100,000 1982-1985 down to 4.9 deaths/100 000 for 1991-1994. Leading causes of death; machinery (54%) and electric current (20%). On farm fatalities that were non-occupational: drowning (38.9%) and firearms (28.6%). 1991-1994 drowning and firearms accounted for the same number of on farm deaths as machinery related.

Pickett W et al (2005)	n=370 non-work child injuries. Canada and USA	age, non-work related mechanism activity	Fatal & non-fatal injury, Children under 7 years.	None considered	Children were mainly resident on farms (63%) and under the age of seven years. Leading mechanisms: bystander and passenger runovers (fatalities); drowning (fatalities); machinery entanglements (hospitalisations); falls from heights (hospitalisations); animal trauma (hospitalisations and restricted activities injuries). Activities: playing in the worksite; bystander or extra rider on farm machinery; recreational horseback riding.
Pickett W et al (2007)	n=484 pediatric fall injuries. Canada and USA.	age, activity, work-relatedness, mechanism	Fatal and non-fatal injury, children.	None considered	Fall injuries account for 41% of the case series (484/1193). 20% of the fall injuries were into the path of a moving hazard - complex falls. 91% of complex falls were related to farm production. 61% of complex falls from heights occurred when the children were not working. Fatalities and hospitalisations overrepresented in complex falls.

Rautianen RH et al 2007)	Mortality &morbidity, United States	All workers in agriculture; populations at risk	Fatal and non-fatal injury	None considered	Fatality rate in 1990s 22/100 000 workers. Tractor incidents leading cause of death (300 a year). Non-fatal injuries decreased in this period amongst employed agricultural worker population. Inadequate data on self employed farmers and their families; estimated injury rate 16.6/100 workers. High rates of musculoskeletal and respiratory symptoms; hearing loss and skin disorders. Over-all cancer rate is lower, but specific cancers elevated in farmers. Surveillance methods have not improved over last decade. Need to further define populations at risk: farmers and ranchers, family members, workers, migrant and seasonal workers and others.
Saar et al (2006)	1990-2000; farm injuries fatalities, British Columbia, Canada.	age, gender, cause of injury, primary diagnosis, mechanism	Fatal and non-fatal injury	None considered	82 fatal injuries from 1990-2000; 1407 hospitalisations 1991/92-1999/2000. No significant overall incidence trends in this period. Machinery related hospitalisation rate lower BC than in other parts of Canada. High rates of hospitalisation for non-

				machinery related injury for young adult BC farmers.
Schwab et al (2000)	N=437 cases of auger related injuries Iowa	Work relatedness Perceptions of injuries Condition of augers	Non-fatal	Most common injuries to the finger. Farmers perceptions of potential injury match data on injuries from augers. Revealed that 34% of the primary and secondary augers were unshielded or without guarding.

Shaults RW (2005)	United States 2001-2003 15 years and over	age, gender, body part injured, diagnosis and hospital admission status	Non-fatal injuries	None considered	2001-2003 est. 108 724 children aged 15 yrs and under were treated in hospital Eds for non-fatal injures sustained while riding ATVs. ATV related injuries increased by 25% in this period. 11-15 yr old males accounted for 52% of ED visits and hospitalisations among young riders. 0-5 yrs more likely to have facial injuries; older children more likely to have trunk, leg or foot injuries. Fractures most common diagnosis (27% of ED visits; 45% of hospitalisations). Current legislation does not effectively address rising ATV related injuries.
Sosnowska SK (2007)	Poland, farm related injuries to children. Administrative data.	age, gender, mechanism, work-relatedness.	Non-fatal injuries	None considered	13-15 year old boys falling while working unattended or while assisting in the work performed by adults, inside and around farm facilities, in summer, are the most frequent victims of injury on farms.

Terziioglu A et al (2004)	Anatolia; 58 cases of hand injuries to children	nature of injury, treatment	Non-fatal injuries	None considered	58 cases of hand injuries in children aged 3-7 (mean 4.5) caused by engine belts of agricultural vehicles. Most common injury involved digit and third finger and the thumb the least. Surgery for lacerations, tendon repair, fixation of fractures, grafting and local flaps. Outcomes poor.
Thelin (2002)	1988-1997 Fatal-injury Swedish farming and forestry	Work-relatedness, regulations	Fatal injuries	None considered	Number of fatal injuries occurring at work are decreasing in Sweden - with the exception of those occurring in farming and forestry operations. In farming the rate is 11.6/100 000 and the trends appears to be an increase. Membership of occupational health schemes was lower than expected among victims. Most injuries resulted because the worker or fellow worker did not follow rules or recommendations.

Thorne (2008)	1995-2006 administrative data set, New Zealand.	Work-relatedness, age, gender	Non-fatal injuries	None considered	A review of the burden of occupational noise exposure and hearing loss. Current data on NIHR in NZ unreliable. Accident compensation data reveals a substantial increase in claims annually, 2823 in July 1995-June 1996, to 5580 in July 2005-June 2006. A six-fold cost increase over this decade ($193.82M). Agriculture, fisheries, trades workers, machiner operators, and assemblers accounted for 53% of new claims. Most claimants, middle aged and older, male (95%).
Case Series					
Brison RP et al (2006	1990-2001, children, Canada	age, gender, work-relatedness, location, mechanism	Fatal injuries	None considered	Fatal agricultural injury was substantially higher than that of all-cause, unintentional injury among Canadian children aged 1-6 years (14.9 v 8.7 per 100 000 person-years respectively). Elevated fatal agricultural injury amongst boys. 73% of injuries occurred at worksite and were the result of three mechanisms: run over by machinery as a bystander (29%); extra rider

					fell from machine (22%); asphyxia due to drowning (23%). Pre-school children at major risk of fatal injury.
Franklin & Davies (2003)	384 farm related injury cases. NSW, Australia.	farm activity, commodity type	Hospital presenting injury	None considered	34 injuries per 100 farms. Majority of cases male, employed, resident on farm and meat cattle, cereal and poultry production. Common cause of injury horses, motorcycles, animals and other objects.
Hagel et al (2004)	N=1 493 Hospitalizations For machinery Related injury	Machinery on farms	Hospital presenting injury		Machinery related injuries are the leading cause of fatal and hospitalized injuries on Canadian farms. Older age is a significant predictor of injury.
Nelson et al (2005)	N=187 Children Illinois	ATV injury	Hospital Presenting injury		The incidence of all-terrain vehicle (ATV) injuries is increasing, local injury levels correlate well with national levels.

Smith GAS et al (2004)	96 hospitalized patients, pediatrics, USA.	farm activity, machinery, location	Hospital presenting injury	None considered	96 children admitted over a nine year period. Five children died and one child was discharged with a severe brain injury to a rehabilitation facility. Children aged 6 weeks to 17 years. 40.6% had an animal related injury; Amish children had increased risk of horse related injury than non-Amish children., machinery related injury (38.5%); falls from buildings or haylofts (12.5%). Head trauma in 36.4% of cases, skull fractures (24%).
Windsor et al (2005)	50 primary-producers vaccinating sheep with Gudair vaccine for control of ovine paratuberculosis.	Self inoculation with Gudair vaccine	Injuries resulting from self-inoculation.		Overall rate of one self-inoculation incident per 7406 vaccinations. 21 incidents of exposure with 5 superficial skin contact, 16 penetration without vaccine. 6 cases need medical intervention, 3 extensive surgery.
Prevalence Surveys					
Chapman et al (2003)	N=81 children And adolescents	Age	Range of work tasks		Children and adolescents performed same range of tasks and often the same scope of work as adults. 50% of the adolescents reported LBD and 25%

					reported disabling discomfort.
Depczynski JF et al (2005)	N=48 Agricultural establishments. Australia	farm noise emissions, location, mechanisms, operators and bystanders	Farm visit and noise measurements	None considered	N=48 Agricultural establishments. Noise levels measured at the ears of operators and bystanders. Common noise hazards: firearms, tractors without cabs, workshop tools, small motors (chainsaws, augers, pumps), manual handling of pigs, shearing sheds, older cabbed tractors, and heavy machinery such as harvesters, bulldozers, cotton module presses. Use of firearms without hearing protection a pressing health priority.
Hendricks KJ et.al. (2005)	n=2000 racial minority farms. USA.	age, location, ethnicity, mechanisms	Non-fatal injury and exposure	None considered	Estimated 28 600 household youth on racial minority farms in the US. Of these, 41% worked, 28% rode a horse; 23% drove an ATV; and 23% operated a tractor. On Hispanic farms there are an estimated 17 998 household youth, 41% of whom worked; 30% rode a horse; 27% drove an ATV and 25% operated a tractor.

Hendricks KJ et.al. (2001)	n=26 000 farm households, USA	age, gender, location, mechanisms	Non-fatal animal related to youth	None considered	6 438 animal related on-farm injuries to youth in 1998. 70% occurred to farm residents; 69% work related; males 64% and 41% of these to males younger than 10. 37% involved horse and 31% cattle. Majority of horse related injuries occurred to females and majority of cattle related injuries to males. Most cattle related injuries were also work related, while most horse related injuries were non-work related. 1 out of 5 youth injuries on US farms are animal related.

McCurdy SA et al (2004)	n=1947	age, gender, ethnicity, location, mechanisms	Non-fatal injury, self reported, preceding year	None considered	Survey of 1947 farm operators, 135 farm operators reported 160 farm work related injuries in the preceding year; cumulative incidence for any FWR injury of 6.9%, or a mean of 8.2 FWR injuries per 100 farmers in the preceding year. Multiple injury in same individual occurred more frequently than chance. Sprains and strains most common (29.4%) in back; overexertion most common external cause (24.2%); machinery (14.3%); falls (13%) and animals (12.4%). Factors associated with FWR: white ethnicity; increased annual hours worked on farm; low levels of administrative work; increased time working with stock. Multiple injuries to individual suggested personal and or environmental risk factors.
Park HS et al (2001)	n=287 Iowa male farmers 1992-1994.	age, gender, location, mechanisms	back pain, self reported	None considered	31% of farmers reported daily back pain for a week or more during the past 12 months, compared to 18.5% in the general working population. Middle aged farmers and those with

					additional non-agricultural jobs had the highest risk for back pain.
Reed DB & S (2006)	n=593 (14-19 yrs) who perform work on farms. Kentucky, Iowa and Mississippi.	age, gender, location, mechanisms, protective gear.	injury exposure	None considered	Boys at higher risk of exposure than girls. Boys engaged in more risky behaviour. Hearing and respiratory protection used sparingly and sporadically. Physical symptoms and physician recommendation influenced use of respriatory and hearing protection. 60% of the students reported using equipment with damaged or missing safety shields. Only half most frequently operated tractors with safety bars and seat belts.

Rosecrance & Merleno (2006)	n=499 farmers, Kansas	work-relatedness, location	Self-reported back pain over last 12 months; exposure, risk	None considered	499 farmers contacted, response rate 57.2%. Low back pain most prevalent (37.5%); shoulders (25.9%); knees (23.6%) and neck (22.4%). Close to 60% experienced back pain in at least one of the nine body areas in the previous year. Nearly 1/4 saw a medical practitioner about their back pain; and one in five had to modify their work practices due to low back symptoms in the last year. Kansas farmers had higher rates of low back pain compared to general working population and other farmers in other regions. Kansas - soybean and corn growing region.
Solomon CP et al (2007)	n=10 765 life-time histories and occupational injury. Britain.	age (born between 1933-1977), male, location, mechanisms	self reported; over working life time in agriculture	Adjustments for calendar period and age	Reported incidence of injuries in agriculture higher than statutory reporting. Highest rates were from handling, lifting, carrying (4.9/1000person-years); falls from height (4.6/1000person-years); injury by animals (3.4/1000 person-years). Elevated risks for men who had only recently entered agriculture and those who carried out forestry.

Spengler SE et al (2004)	n=1004 part-time male farmers Kentucky.	age, male, ethnicity	Self-reported sleep habits and injury occurrence requiring medical attention in the last 12 months.	None considered	12% reported an injury requiring medical attention in the last year. Farmers reported sleeping an average of 7.6 hours daily. 6.7% of the sample reported symptoms of sleep apnea. Hours of sleep were not related to injury incidence. Sleep medication and the presence of sleep apnea symptoms were related to injury incidence.
On-site observational + survey					
Allread et al (2004)	N=15	Males and females Age	Observed 40 farm tasks		Small sample but LBD loads for these children for some tasks equivalent or greater than those associated with high injury risk occupations in industrial workplaces.
Earle-Richardson et al (2004)	14 orchard workers	Activities	2,900 observations over four days		Researchers concluded apple harvest work is comparable with other ergonomically high-risk occupations. Future research should focus on low cost interventions to reduce load and awkward postures.

Wilkinson T & S Field (2005)	Purdue University data base. USA	mechanism, location, time	Exposure to power-take off driven augers.	None considered	Exposure to conventional grain augers while unloading from trucks and wagons, extended dump hopper augers, and swing-away hopper augers. Operators had higher exposure time to operating PTO components when the driveline was located on the right side of the grain auger; as one sgtands facing the hopper end of the auger, than on the left side of the auger when using conventional grain augers and grain trucks. This added exposure was due to the position of the driver's door of the truck, the natural path of the driver from the operators seat to the rear of the truck and the movement of the truck body into the workspace when tilted. Operators had highest exposure when using conventional grain augers and gravity flow grain wagons. Operators had no recorded exposure time when operating swing-away hopper augers. Recommend reconfiguring the way augers are incorporated into grain handling operations.

Medical Screenings					
Gorlia VG et al (2006)	3 tractors	vibration, location, idling, in motion and while conducting soil tillage	measuring vibration levels of tractors, exposure to hand-arm vibrations	None considered	Results showed that 10% of workers are exposed to a risk of vibration induced white finger disorder of the hands after relatively short periods (3-4 years) - if the tractor is used 8 hours per day in soil tillage and transportation at full load.
Milosavljevic S et al (2005)	n=64 shearers and 64 non-shearers	posture while shearing	Present previous back pain	None considered	Shearers appear to lose lumbar extension, gain hip flexion and develop an adaptive normal stance. This adaptation appears to be independent of previous or current back pain. Lumbar extension loss in non-shearers correlates with previous back injury. Occupation is the predominant influence on motion and posture, followed by age.

Appendix C

Risk factors for occupational disease amongst agricultural workers - summary of epidemiological evidence by study design, disease, risk and exposure

Study design	Participants	Nature of research	Exposure	Results
Cohort Studies				
Cancers				
Beane F et al (2005)	n=23,106 male applicators in Iowa and North Carolina.	Routine application of diazinon (organophosphate insecticide) and association with cancer risk.	Two quantitative exposure metrics were used: lifetime exposure days and intensity-weighted lifetime exposure days, a measure that incorporates probability of pesticide exposure with lifetime pesticide application and frequency.	When life time exposure days were used, increased risks for the highest tertile of exposure and significant tests for trend for lung cancer and leukemia were observed. No other cancer site showed an association with diazinon for the highest tertile of exposure.
Blair AS et al (2005b)	n=89 658 pesticide applicators and their spouses. Iowa and North Carolina (1993-1997).	Agricultural exposure and risk factors for disease; links to pesticides		Compared to general population of the two states the cohort experienced a low mortality rate overall for specific causes and a low rate of overall cancer evidence. Some cancers did appear elevated: multiple myeloma, cancers of the lip, gallbladder, ovary, prostate, and thyroid, but numbers were small for many cancers. Some association found with exposure to several pesticides and prostate cancer, especially among individuals with a family history of prostate cancer. Pesticide and other agricultural factors linked to: injuries, retinal degeneration, and respiratory wheeze.

Bonner MC (2007)	n=19 717 pesticide applicators, 1993-1997, Iowa and North Carolina	Associations between Malathion (most common organophosphate insecticide applied in the US and cancer amongst pesticide applicators.	Information on life time years and days per year of use and intensity of malathion exposure obtained through self-administered questionnaires prior to the onset of any cancer. Follow-up average 7.5 years (1993-2002)	Rate ratios and 95% confidence intervals were calculated using Poisson regression, adjustments made for potential confounders. Lifetime days of malathion use (top tertile of exposure, >39 days) not associated with all cancers combined. Risk of non-Hodgkin's Lymphoma was not associated with malathion use - but the number of cases was small. Risk of melanoma with more than 39 lifetime exposure days was 0.39. In sum, malathion use was not clearly associated with cancer. The rate ratios for melanoma were reduced; small numbers and lack of experimental evidence suggest that these reductions may have arisen by chance.
Bonner ML et al (2005)	n=49 877 licensed pesticide applicators in Iowa and North Carolina.	Exposure to carbofuran a carbamate insecticide used for a variety of food crops including corn, alfalfa, rice, and tobacco. Nitrosated carbofuran has demonstrated mutagenic properties.	Obtained information on years of use, frequency of use in an average year, and when use began for 22 pesticides using self-administered questionnaires. Poisson regression used to calculate rate ratios (RR) and 95% confidence intervals (Cis), adjusting for potential confounders.	Lung cancer was three-fold higher for those with >109 days of lifetime exposure to carbofuran; compared with those with <9 lifetime exposure days, with a significant dose-response trend for both days of use per year and total years of use. Carbofuran was not associated with lung cancer risk in non-exposed persons used as a referent. Carbofuran was not associated with any other cancer site examined. These results should be used cautiously as there was no apriori hypothesis specifically linking carbofuran with lung cancer.
De Roos AB et al (2005)	n=57 311 licensed pesticide applicators in Iowa and North Carolina	Associations between exposure to Glyphosate (a broad spectrum herbicide and one of the most frequently applied in the world) and cancer incidence amongst licensed pesticide applicators.	Self administered questionnaire recorded information on pesticide use. Exposure was defined as a) ever personally mixed or applied products containing glyphosate; b) cumulative lifetime days of use or "cumulative exposure days" (years of use x days/year); and c)intensity-weighted cumulative exposure days (years of use x days/year x estimated intensity level). Poisson regression used to estimate exposure-response relations between glyphosphate and incidence of all cancers and 12 relatively common cancer subtypes.	Glyphosate exposure was not associated with cancer incidence overall or with most cancer subtypes. Suggested association with multiple myeloma incidences which should be followed up as more cases occur in this study.

Dinham B et al (2005)	n=?? Where??	Associations between exposure to four of the most commonly used agricultural pesticides (diazinon, dieldrin, metalochlor and pendimethalin) and lung cancer.	Not explained?	Significant increased risk of lung cancer amongst those with greatest exposure compared with those who had no exposure. Three other pesticides: carbofuran, cholorpyrifos, and dicamba, also increased the risk of lung cancer (but the results were not statistically significant). Increased risk for lung cancer only for those with prolonged exposure to diazinon, dieldrin, metalochlor and pendimethalin.
Engel LH et al (2005)	n= 30 454 women with no history of breast cancer, Iowa and North Carolina.	Association between pesticide use and breast cancer incidence among farmers wives.	Self administered questionnaire on pesticide use and other exposure information.	There was some evidence of increased risk associated with use of 2, 4, 5-trichloro-phenoxypropionic acid (2,4,5,TP) and possibly use of dieldrin, and captan, but small numbers amongst those who had personally used the pesticides precludes firm conclusions. No clear association was found with farm size or washing clothes worn for pesticide application, however, risk was modestly elevated for women whose homes were closed to areas of pesticide application. Further follow-up necessary.

Hou LL et al (2006)	n=9 089 pendimethalin exposed; and n= 15 285 nonpendimethalin-exposed pesticide applicators. Iowa and North Carolina	Exposure to pendimethalin (herbicide) use among pesticide applicators and incidence of cancer.	Two questionnaires, one on enrollment and one take home. Poisson regression analysis was used to evaluate the association of pendimethalin exposure with cancer incidence (mean follow-up 7.5 years) using two exposure metrics: tertiles of lifetime days of exposure and tertiles of intensity-weighted lifetime days of exposure.	Cancer incidence did not increase with increasing lifetime pendimethalin use. There was no clear evidence of an association between pendimethalin use and risks for specific cancers. The risk for rectal cancer rose with increasing lifetime pendimethalin exposure when using nonexposed as the reference, but the association weas attenuated when using the low exposed referent group. Similar patterns for rectal cancer were observed when using intensity-weighted exposure-days. The number of rectal cancer cases among the pendimethalin-exposed was small (n=19). Some evidence for an elevated cancer risk for lung cancer, but the excess only occurred in the highest exposure category for lifetime pendimethalin exposure. Trends for lung cancer risk were inconsistent for different exposure metrics. Overall, did not find a clear association of lifetime pendimethalin exposure either with overall cancer incidence or with specific cancer sites.
Koutros SM et al (2008)	n=57 311 licensed pesticide applicators in Iowa and North Carolina. 1993-1997 (AHS cohort).	Exposure to DDVP (2,2 Dichloroethenyl dimethylphosphate) exposure among pesticide applicators.	Questionnaire collected exposure information on DDVP and potential confounders. 4,613 respondents reporting using DDVP. DDVP exposure was classified as intensity-weighted cumulative exposure days (IWED), calculated as [years of use x days per year x intensity level]. Poisson regression analysis was used to calculate rate ratios (RR) and 95% confidence levels (CI) to evaluate the association of DDVP exposure among 2 943 incident cases of cancer.	DDVP exposure was not associated with any cancer in this study. No observed elevation of risk among lymphohematopoietic cancers and a small excess risk associated with exposure among those with a family history of prostate cancer. Little evidence of an association between cumulative lifetime use of DDVP and risk of any cancer at this stage of the follow-up of the AHS study.

Lee W et al (2004)	n=49 980 licensed pesticide applicators in Iowa and North Carolina. (AHS cohort).	Exposure to alachlor and incidence of cancer amongst pesticide applicators.	Pesticide exposure information and other information were obtained through a self administered questionnaire at the time of enrollment (1993-1997) Poisson regression analysis was used to evaluate the exposure-response relations between alachlor and cancer incidence controlled for the effects of potential confounding factors.	Among alachlor exposed applicators there was significant increasing trend for incidence of all lymphohematopoietic cancers associated with lifetime exposure days (p for trend =0.02) and intensity-weighted exposure days (p for trend=0.03) to alachlor. Risks of leukemia and multiple myeloma were increased among applicators in the highest alachlor exposure category. A possible association between alachlor application and incidence of lymphohematopoietic cancers amongst applicators.
Lee WS et al (2007)	n=56 813 pesticide applicators with no prior history of colorectal cancer. Iowa and North Carolina 1993-1997 (AHS cohort)	Exposure to pesticides and incidence of colorectal cancer.	Pesticide exposure information was obtained through self administered questionnaires completed at the time of enrolment (1993-1997). Cancer incidence was determined through population-based cancer registries from enrollment through to 2002.	Although most of the 50 pesticides studied were not associated with colorectal cancer risk, chlorpyrifos use showed a significant exposure response trend for rectal cancer (p for trend= 0.008) rising to a 2.7 fold (95% confidence interval: 1.2-6.4) increased risk in the highest exposure category. Aldicarb was associated with a significantly increased risk of colon cancer (p for trend=0.01, based on a small number of exposed cases, with the highest exposure category resulting in a 4.1 fold increased risk (95% confidence interval:1.3-12.8). Dichlorophenoxyacetic acid showed a significant inverse association with colon cancer but the association was not monotonic. The findings should be treated with caution as the literature suggesting pesticides are related to colorectal cancer is limited. However, there is a possibility of an association between exposure to certain pesticides and incidence of colorectal cancer among pesticide applicators and further research is necessary.

Lynch SR et al (2006)	n=57 311 licensed pesticide applicators, Iowa and North Carolina 1993-1997 (AHS cohort)	Exposure to cyanazine and cancer incidence amongst pesticide applicators.	Pesticide exposure information from a self-administered questionnaire on enrollment (1993-1997). Cancer incidence was followed through to January 2002. Over half of the applicators had > than or = to 6 years of exposure on enrollment and approximately 85% had begun using cyanazine before the 1990s. Poisson regression was used to calculate rate ratios (RR) and 95% confidence intervals (CIs) of multiple cancer sites among cyanazine-exposed applicators. Calculated p sub (trend) values, and all statistical tests were two-sided. Two exposure metrics were used: tertiles of lifetime days or exposure (LD) and intensity weighted (LD)	No clear, consistent associations with cyanazine exposure and any cancer analysed in this study. The number of sites was small for certain cancers, limiting any conclusion with regard to ovarian, breast and some other cancers.
Mahajan RB et al (2007)	n=21 416 subjects (1 291 cases) 1993-1997, Iowa and North Carolina (AHS cohort)	Exposure to carbaryl (carbamate insecticide) amongst pesticide applicators and incidence of cancer.	Pesticide exposure information collected through a self administered questionnaire. Poisson regression used to calculate rate ratios (RR) and 95% confidence intervals (Cis) while controlling for potential confounders.	Carbaryl was not associated with cancer risk overall. Relative to subjects who never used carbaryl, melanoma risk was elevated with >175 lifetime exposure-days (RR = 4.11; 95% CI, 1.33-12.75; p trend = 0.07); >10 years of use (RR = 3.19; 95% CI, 1.28-7.92; p-trend = 0.04), or >or=10 dyas of use per year (RR =5.50; 95% CI, 2.19-13.84; p-trend <0.001). Risk remained after adjusting for sunlight exposure. Although not significant there appeared to be a trend of decreasing prostate cancer risk with increasing level of exposure. A small increase in NHL risk was observed using some, but not all, exposure measures. No associations were observed with other examined cancer sites. Observed results were not hypothesised apriori and limited study of their biological plausibility means that the results should be treated with caution.

Mahajan RB et al (2006)	n=45 372 pesticide applicators, Iowa and North Carolina, 1993-1997 (AHS cohort)	Exposure to fonofos and risk of cancer	pesticide exposure information was collected through a self administered questionnaire. Poisson regression was used to calculate rate ratios (RR) and 95% confidence intervals (Cis) while controlling for potential confounders.	Relative to the unexposed, leukemia risk was elevated in the highest category of life time and intensity-weighted exposure days, a measure that takes into account factors that might modify pesticide exposure. Risk of prostate cancer was not related to fonofos use overall, however among applicators with a family history of prostate cancer a significant dose-response trend for lifetime exposure-days was observed. Intensity weighted results were similar. No associations were observed with other examined cancer sites. Further research is needed to confirm findings with respect to Leukemia and to determine if genetic susceptibility modifies prostate cancer risk from pesticide exposure.
Mahajan RB et al (2006)	n=45 372 pesticide applicators, Iowa and North Carolina, 1993-1997 (AHS cohort)	Phorate exposure and overall cancer incidence	Three years of follow up on preceding research using more details exposure data. Data was collected via self administered questionnaires completed from 1993-1997. Poisson regression was used to calculate rate ratios (RR) and 95% confidence intervals (CIs) adjusting for potential confounders.	Phorate use was not related to incidence in all cancers combined or to any individual cancer. However there were insufficient numbers to study non-Hodgkin lymphoma or leukemia which have been linked to organophosphates in other studies. Prostate cancer was not significantly related to phorate use overall or among those without a family history, the risk increased among pesticide applicators with a family history of prostate cancer. The observed statistical interaction suggests a gene-environment interaction between family history and phorate exposure in the incidence of prostate cancer, but other explanations are possible.
Nordby KA et al (2004)	n=131 243 male Norwegian farmers born 1925-1971.	Exposure to immunosuppressive substances (eg. Mycotoxins, pesticides) and lip cancer incidence.	A cohort of 131,243 male farmers born between 1925-1971 established by cross-linkage of national registers and followed up thourhg 1999 for incidence of lip cancer in the Cancer Registry of Norway. Farm production data from agricultural censuses and meteorological data on solar radiation and fungal forecasts served as exposure proxies. Adjusted rate ratios	108 lip cancer cases (rate 4.4 per 100 000 person-years). We found LC to be moderately associated with horses on the farm; construction work employment; pesticide use; grain production and increasing levels of fungal forecasts. Moderate associations of lip cancer with grain production and fungal forecasts and the negative association with pesticide could possibly be explained by exposure to immunosuppressive mycotoxins. Some of the associations observed could

			(RR) and 95% confidence intervals (CI) were estimated using Poisson regression.	be explained by solar exposure.
Mortality and pesticides				
Blair AS et al (2005)	n=52 393 applicators and n= 32 345 spouses of farmers in Iowa and North Carolina.	Mortality experience of pesticide applicators and their spouses.	At enrollment applicators completed an enrollment questionnaire. Mortality assessment from enrollment (1994-1997) through 2000 provided an average follow-up of about 5.3 years, 447 154 person years, and 2055 deaths.	When compared to the general population in the two states, the cohort experienced a very low mortality rate. Several factors might have contributed to this low mortality rate, including health worker effect typically seen in cohorts of working populations and where this may decline in the future; a short follow-up interval; healthier lifestyle manifest in low cigarette use and an occupational that has traditionally demanded high levels of physical activity.
Lee WJ et al (2007)	n=55 071 pesticide applicators (AHS study) Iowa and North Carolina.	Evaluate whether agricultural chlorpyrifos exposure was associated with mortality.	Information was obtained through self administered questionnaires completed at the time of enrollment (1993-1997). Lifetime chlorpyrifos use was divided into tertiles. Poisson regression analysis was used to evaluate the exposure-response relationships between chlorpyrifos use and causes of death after adjustment for potential confounders.	A total of 1 851 deaths (588 among chlopyrifos users) were observed during the study period, 1993-2001. The relative risk(RR) of death from all causes combined among applicators exposed to chlorpyrifos was slightly lower than that for non-exposed applicators. For most causes of death analysed there was no evidence of an exposure-response relationship. However, the relative risks for mortality from suicide and non-motor vehicle accidents increased 2 fold in the highest category of chlorpyrifos exposure days. These results were however based on small numbers, but suggest that there may be a link between chlopyrifos and depression and other neurobehavioural symptoms that needs to be explored more fully.

tMannetje A et al (2005)	n= 1025 Phenoxy herbicide producers; n=703 sprayers. January 1969 - 31 December 2000. New Zealand.	Exposure to dioxin and phenoxy herbicides and mortality.	A total of 813 producers and 699 sprayers were classified as exposed to dioxin and phenoxy herbicides. Standardised mortality ratios (SMR) were calculated using national morbidity rates.	24% non-significant excess cancer mortgality in phenoxy herbicide producers, with a significant excess for multiple myeloma. Associations were stronger for those exposed to multiple agents including dioxin during production. Overall, cancer mortality was not increased for producers and sprayers mainly handling final technical products, although they were likely to have been exposed to TCDD levels far higher than those currently in the general New Zealand population.
Respiratory conditions				
Chaudemanche J et al (2003)	n=215 dairy farmers, n=110 controls, France, cohort estb in 1994.	Respiratory status of dairy farmers and that of non-farming controls.	Protocol comprised a medical and occupational questionnaire, spirometric tests at both evaluations, alleergological tests at T1, and a non-invasive measure of blood oxygen saturation (SpO2) at T2.	Dairy farming is associated with excess of chronic bronchitis, with a moderate degree of bronchial obstruction and a mild decrease in SpO2.
Gainet MT et al (2007)	n=157 dairy farmers and n=159 controls. Cohort established in 1986 and reevaluated in 1998.	Prevalence of respiratory conditions and farm exposures	Study protocol comprised a medical and occupational questionnaire, spirometric tests at both evaluations and noninvasive measure of blood oxygen saturation with pulse osimetry.	In 1998, the prevalence of chronic bronchitis was higher in dairy farmers. The overall results demonstrated that dairy farming is associated with an increased risk of lung disorders and a decrease in blood oxygen saturation and suggests that respiratory function impairment is correlated with cumulated exposure to organic dusts.

Hoppin JA et al (2002)	n=20 468 applicators in Iowa and North Carolina (16-88 yrs)	Association between wheeze and pesticide use in the last year.	Self administered questionnaires addressing 40 currently used pesticides and pesticide application practices.	19% reported wheeze in the last year. Logistic regression models controlling for age, state, smoking, history of asthma or atopy were used to evaluate associations between individual pesticides and wheeze. Of those pesticides suspected of contributing to wheeze, paraquat, three organophosphates (parathion, malathion, and chlorpyrifos) and one thiocarbamate (S-ethyl-dipropylthiocarbamate (EPTC) had elevated odds rations (OR). Parathion had the highest OR (1.5, 95% confidence interval [CI] 1.0, 2.2). Chlorpyrifos, EPTC, paraquat, and parathion demonstrated significant dose-response trends. The herbicides, atrazine and alachlor, but not 2,4-D, were associated with wheeze. Atrazine had a significant dose-reponse trend with participants applying atrazine more than 20 days/year having an OR of 1.5 (95% CI 1.2, 1.9). Inclusion of crops and animals into these models did not significantly alter the observed OR. While these associations are small they suggest an independent role for specific pesticides in respiratory symptoms of farmers.

Hoppin JA et al (2003)	n= 20 468 pesticide applicators, Iowa and North Carolina.	Wheeze associated with animal production. Exposure to animals, their feeds, and by-products contribute to respiratory symptoms. Assess whether the impact varies among subgroups: atopics, asthmatics and smokers.	Individuals raising animals requiring direct contact had the highest odd ratios (OR) for wheeze (OR (dairy)=1.26; OR(eggs) = 1.70. A significant dose response was observed for both the number of poultry and the number of livestock on the farm. Those who performed veterinary procedures had an OR of 1.51. Odds of wheeze associated with poultry production was greater among atopic than non-atopic individuals. Milking cows daily increased the odds of wheeze for all individuals, the largest association being for those who were atopic asthmatic individuals. The impacty of poultry, diary, and egg production varied among smoking groups. Past smokers had the highest odds ratios, followed by never smokers, and then current smokers. The OR (eggs) was 2.88 among past smokers but only 1.46 for never smokers. The OR(eggs) for current smokers of 0.80 might reflect self selection of exposure among smokers. Results are consistent with animal production and respiratory symptoms and suggest subgroups (atopic, asthmatics and smokers) respond differently to exposure.

Hoppin JA et al (2004)	n= 20 898 pesticide applicators in Iowa and North Carolina	Exposure to diesel exhaust, solvents, welding fumes and other respiratory irritants. Evaluating the odds of wheeze associated with non-pesticide occupational exposures.	Self administered questionnaires.	Logistic regression models controlling for age, state, smoking and history of asthma or atopy to evaluate the odds of wheeze over the last 12 months. Driving diesel tractors was associated with elevated odds of wheeze (OR = 1.31; 95% confidence interval - 1.13, 1.52); the odds ratio for driving gasoline tractors was 1.11 (95% confidence interval =1.02, 1.21). A duration-response relationship was observed for driving diesel tractors but not for driving gasoline tractors. Activities involving exposure to solvents (painting and cleaning) were associated with increased odds of wheeze in a duration-dependent way. The highest odds of wheeze for farm activities were from daily painting, an indication of daily solvent exposure. These results add to a growing body of evidence that exposure to diesel and solvents can have adverse respiratory effects.
Hoppin JA et al (2006)	n=89 000 licensed pesticide applicators and their spouses. Iowa and North Carolina.	Exposure to pesticides and respiratory outcomes including: wheeze, adult asthma, farmers lung, and chronic bronchitis.D12	Self administered questionnaires - exposure and use of 40 individual pesticides.	19% of farmers and 22% of commercial pesticide applicators reported wheeze in the previous year. Using logistic regression models adjusted for age, state, smoking status, and body mass index we evaluated the association of 40 individual pesticides with wheeze within these two groups, separately. For both groups there was strong evidence of an association between organophophates and wheeze. For farmers: the organophosphates, chlorpyfios, malathion, and parathion were positively associated with wheeze. Commercial applicators: the organophosphates , chlorpyrifos, dichlorvos, and phorate were positively associated with wheeze. Chlorpyrifos was strongly associated with wheeze in a dose-dependent manner in both groups; use of chlorpyrifos for at least 20 days per year had an odds ratio of 1.48(95% confidence interval (CI) = 1.00-2.19) for farmers and 1.96 (95% CI=1.05-3.66) for commerical applicators.

Hoppin JA et al (2006)	n=2 255 Iowa pesticide applicators	Association of pesticides with wheeze in a population without other farming exposures.	Controlling for age, smoking status, asthma and atopy history and body mass index odds ratios were calculated for the relationship between wheeze and 36 individual pesticides participants had used during the year before enrollment (1993-1997).	Eight of the 16 herbicides were associated with wheeze in single-agent models; however the risk was almost exclusively associated with the herbicide chorimuron-ethyl (odds ratio (OR) =1.62, 95% confidence interval (CI): 1.25, 2.10). Inclusion of chlorimuron-ethyl in models for other herbicides virtually eliminated the associations. The odds ratios for four organophosphate insecticides (terbufos, fonofos, chlorpyrifos and phorate) were elevated when modelled individually and remained elevated, though attenuated a little, when chlorimuron-ethyl was included. The association of dicholorvos was not attenuated by cholorimuron-ethyl (OR =2.48, 95%CI: 1.08, 5.66). Dose response trends were observed for chlorimuron-ethyl, chlorpyrifos, and phorate, the strongest OR was for applying chlorpyrifos on more than 40 days per year (OR=2.48, 95% CI: 1.24, 4.65.
Iversen MD (2000)	N=181 Danish farmers (seven year follow-up)	Working in swine confinement buildings exposure to organic dust and airway obstruction		Working in swine confinement units causes an accelerated decline in forced expiratory volume in one second but not in forced vital capacity. The mean decline is approximately 0.5L during a working life and some farmers will develop clinically significant airway obstruction due to work in swine confinement units.
Merchant MN et al (2005)	N=?? Iowa children	Association between farm and other environmental risk factors with four asthma outcomes: 1) doctor diagnosed asthma; 2) doctor diagnosed asthma/medication for wheeze, current wheeze, and cough with exercise.		Multivariable models of the four health outcomes found independent associations between male sex, age, a personal history of allergies, family history of allergic disease, premature birth, early respiratory infection, high-risk birth, and farm exposure to raising swine and adding antibiotics to feed.

Musken JF et al (2000)	n=86 German farmers with rhinitis and/or asthma.	Exposure to house dust and storage mites and allergic airways disease.	Data was collected by skin prick testing and/or enzyme allergosorbent test (EAST) with the following mites: Blomia tjibodas, Blomia tropicalis, Blomia kulaginin, Glycyphasgus domesticus, Thyreophasgus entomophagus, Euroglyphus maynei, Chortoglyphus arcutas, Dermatophagoides pteronyssinus, Derma tophagoides farinae, Acarus siro, Lepidoglyphus destructor, Tyrophagus putrescentiae, Acarus farris and Cheyletus eruditus.	The most frequent sensitisations determined by skin tests were found for the three blomia species, E maynei and G domesticus. A considerable proportion of German farmers tested were sensitised to storage mites. It was concluded that B tjibodas, G. domesticus, C. arcuatus and C. eruditus in particular should be included in an allergy diagnosis. Further research is necessary into clinical relevance of the sensitisations and possible cross-reactivity between mite species.
Valcin MH et al (2007)	n=21 541 nonsmoking women, Iowa and North Carolina (AHS cohort)	Agricultural risk factors for chronic bronchitis among non-smoking farm women.	Self administered questionnaire. Odds ratios (Ors) were adjusted for age, state, and related agricultural exposures.	Applying manure and driving combines were independently associated with chronic bronchitis. Off farm job exposures associated with chronic bronchitis were organic dusts, asbestos, gasoline, and solvents. Five pesticides were also associated with chronic bronchitis after mulitvariate adjustment and sensitivity analyses: dicholorvos; cyanazine; paraquat; and methyl bromide. Pesticides, grain and dust exposures were associated with chronic bronchitis among non-smoking farm women.
Vogelzang PF et al (2000)	n=171 pig farmers, followed over three years.	Exposure-response relationships - dust and ammonia and respiratory conditions among pig farmers.	Bronchial responsiveness was assessed by a histamine provocation test. Long term average exposure to inhalable dust and endotoxins was determined by personal monitoring in summer and winter. Recorded data on farm characteristics and activities.	Exposure to dust and ammonia in pig farms contributes to chronic inflammation of the airways and should be reduced.

Cardiovascular disease and risk factors				
McCarty CC et al (2002)	n=675 farm residents and n= 825 nonfarm residents. Women. Wisconsin.	To describe base line difference in cardiovascular disease risk factors between farm and non-farm women in a geographically defined area.	Baseline examination included measurements of blood pressure, skin folds, height, weight, fasting blook lipids, and blood glucose. Health behaviour data also collected on smoking, dietary intake, reproductive health, physical activity, medical history, social support, occupational strain, and symptoms of anxiety and depression.	Farm residents and non-farm residents were of similar age (mean 47.6 and 47.0). The results suggest that the prevalence of risk factors for atherosclerosis and hence future coronary heart disease is very high in rural women. Obesity reduction programs should target rural women, and cease smoking campaigns should target non-rural women.
Health status				
Merchant JA et al (2002)	Keokuk County Rural Health Study.	To describe, measure and analyse prevalent rural and agriculturally related adverse health outcomes and risk factors	In-person interviews, medical screenings, environmental assessments of home and farms. All households were rural, comparisons made among farm, rural non-farm, town households, between men and women, smokers and non-smokers.	Residents of farm households were younger, better educated and smoked less than residents of rural nonfarm and town households. Men more often reported hearing loss, were more often overweight and obese, more often reported injury, less often reported asthma and less often saw a medical practitioner. Women reported poorer emotional health and higher rates of depression symptoms.
Mental Health - Depression Osteoarthritis				
Thelin AH (2007)	n=1220 farmers, 1330 matched rural non-farming men, and 1087 urban men. Sweden.	Risk of developing osteoarthritis of the hip joint, occupational use.	Identified in 1989 and followed up over time. Information obtained from Swedish register of hospital care and surgery.	Farmers but not non-farming rural men had a significantly increased risk of developing osteoarthritis of the hip joint as compared with urban referents.
Case Control Studies pesticide exposure	n=5 970 farmer applicators, of which 36 met the criteria.	A nested case control analysis of high pesticide exposure events (HPEEs) amongst Iowa farmers.	Criteria- reporting an incident with fertilizers, weed killers and other pesticides that caused an unusually high personal exposure resulting in physical symptoms or a visit to a health care	Significant risk factors included: poor financial condition of the farm, a high score on a risk acceptance scale. Statistically weak sample.

			provider or hospital.	
Alvanja MS et al (2001)	n=306 cases and n=612 controls farmers; spouses n=63 cases and n=126 controls.	A nested case control analysis of high pesticide exposure events (HPEEs) among Iowa farmers, non-farmers, farmer spouses and non-farmer spouses.	Analysis of factors associated with reporting a high pesticide exposure event by pesticide applicators and their spouses during the five years since enrollment in the AHS study (Iowa and North Carolina)	Pesticide applicators in Iowa had a much greater HPEE (8.8/1000 applicators) than applicators in North Carolina (2.0/1000). Spouses reported (2.0/1000).Only 13% of applicators and 22% of their spouses with symptoms resulting from HPEE sought medical care, suggesting underreporting in surveillance data.
Bell ES et al (2006)	n=25 farm households and n=25 nonfarm households, Iowa.	Investigation of pesticide contamination inside homes.	Air, surface wipe, and dust samples were collected. Samples from 39 homes were analysed (20F,19NF) for atrazine, metolachlor, acetochlor, alachlor, and cholopyrifos. Samples from 11 homes (5F and 6NF) were analysed for glyphosphate and 2.4 Dciholorophenoxyac etic acid (2.4D).	The distributions of the pesticides throughout the various rooms sampled suggest that the strictly agricultural herbicides atrazine and metoachlor are potentially being brought into the home on the farmer's shoes and clothing. They appear to be getting into the home para-occupationally.
Curwin BH et al (2005)	n=959 prevalent cases of parkinsonism (767 with Parkinson's disease) and 1989 controls in Scotland, Italy, Sweden, Romania and Malta.	Investigation of the associations between Parkinson's disease and other degenerative parkinsonia syndromes and environmental factors in five European countries.	Cases were defined using the United Kingdom Parkinson's Disease Society Brain Bank criteria with those with drug induced or vascular parkinsonism or dementia being excluded. Interviewer administered questionnaire about lifetime occupational and hobby exposure to solvents, pesticides, iron, copper and manganese. Multiple logistic regression, adjusting for age, sex, country, tobacco use, ever knocked unconscious and family history of Parkinson's disease.	The association of pesticide exposure with Parkinson's disease suggests a causative role. Repeated traumatic loss of consciousness is associated with increased risk.

Dick FD et al (2007)	Men and women diagnosed with adenocarcinoma of the stomach (n=170); or oesophagus (n=137) between 1988 and 1993. Controls (n=502)	Evaluation of the risk of the stomach and oesophageal adenocarcinomas associated with farming and agricultural pesticide use.	Unconditional logical regression was used to calculate adjusted odds ratios (ORs)for farming and for use of individual and chemical classes of insecticides and herbicides, including pesticides classified as nitrosatable. Non-farmers were the reference category.	No significant associations were found between specific agricultural pesticide exposures and the risk of stomach or oesophagael adenocarcinomas among Nebraska farmers.
Lee WJ et al (2004)	n=251 men and women diagnosed with glioma between 1988-1993. Controls n=498. Nebraska, USA.	Evaluate the risk of the adult glioma associated with farming and agricultural pesticide use in Nebraska.	Unconditional logical regression was used to calculate adjusted odds ratios (Ors) for farming and for use of individual and chemical classes of insecticides and herbicides, including pesticides classified as nitrosatable (able to form N-nitroso compounds upon reaction with nitrite. Non-farmers were used as the reference category for all analyses.	Significant associations between some specific agricultural pesticide exposures for male farmers. Ors were significantly increased for the herbicides mertribuzin and paraquat, and for the insecticides bufencarb, cholorpyrifos and coumaphos.
Lee W J et al (2005)	Incident cases of brain tumour: n=221 and n=442 controls	Relationship between exposure to pesticides and brain tumors in adults. Southwestern France.	Population based case-control study in southwestern France. Histories of occupational and environmental exposures, medical and lifestyle information were collected Cumulative index created. Separate analyses performed for gliomas and meningiomas.	The data suggested that a high level of occupational exposure to pesticides might be associated with an excess risk of brain tumors, and especially gliomas.
Provost, D et al (2007)	Patients diagnosed with Lymphoma, four hospitals between 1998-2002 in Spain.	Estimate the risk of lymphoma among farmers in Spain.	Occupational histories taken, exposures, type of farming. Occupational exposures summarised into 15 main categories.	Although farmers were not at an increased risk of lymphoma when compared to other occupations, farmers exposed to non-arsenic pesticides were found to have an increased risk of lymphoma with risk highest for those exposed for over nine years.

Cancers

Van Balen E et al (2006)	n=341 female glioma cases and n=528 controls .All adult (18-80 years) nonmetropolitan residents of Iowa, Michigan, Minnesota, and Wisconsin.	Gliomas and farm pesticide exposure for women	Adjustments for age, age group, education, farm residence.	Exposure to pesticides was not associated with an increased risk of intracranial gliomas in women. Other farm related factors could be etiologic factors. (NB other studies have noted an excess incidence in male farmers of brain cancers).
Duell E et al (2000)	n=862 cases and 790 controls, North Carolina. 1993-1996.	Farming exposures and breast cancer	Exposure information through personal interview. ORs and 95% confidence intervals.	Results show a possible increased risk of breast cancer among a subgroup of farming women who are most likely to be exposed to pesticides.
Fitschi L et al (2005)	n=694 cases with incident non-Hodgkin's lymphoma in two Australian states and; n=694 controls chosen from Australian electoral rolls.	Occupational exposure to pesticides and risk of non-Hodgkin's Lumphoma.	Logistic regression was used to estimate the risks of non-Hodgkin's lymphoma associated with exposure to subgroups of pesticides after adjustment of age, sex, ethnic origin and residence. Approximately 10% of the cases and controls had incurred pesticide exposures.	Substantial exposure to any pesticide was associated with a trebling of risk on non-Hodgkin's lymphoma. Subjects with substantial exposure to organochlorines, organophosphates and "other pesticides" (excluding herbicides) and herbicides other than phonoxy herbicides had similarly increased risks. However, statistically significant only for "other pesticides". These results are consistent with other research results.
	n=606 men diagnosed with confirmed prostate cancer, n=400 men who had undergone their first prostatectomy for BPH and n=471 male controls. Australia.	Assess the association of selected occupational exposures with risk of prostate cancer and with risk of benign prostatic hyperplasma (BPH).	Population based case control study, August 2001-1 October 2002 in Western Australia, [chi2] tests and logistic regressions used for univariate and multivariate analyses to investigate two outcomes with occupational exposure to pesticides, fertilisers, metals, wood dust, oils, diesel exhaust and polyaromatic hydrocarbons (PAHs).	These results do not provide evidence that any of the occupational factors examined are risk factors for either prostate cancer or BPH.

tMannetje A et al (2007)	n=291 incident cases of NHL (25-70 years). NZ cancer registry 2003-2004. n=471 population controls. New Zealand.	Nationwide case control study to assess whether previously observed occupational associations with non-Hodgkin's lymphoma in New Zealand persist.	A questionnaire to collect demographic information and a full occupational history. The relative risk for NHL associated with employment in particular occupations was calculated by unconditional logistic regression adjusting for age, sex, smoking, ethnicity and socioeconomic status. Estimates were then semi-Bayes adjusted to account for the large number of occupations and industries being considered.	Elevated risk for NHL was observed for field crop and vegetable growers, and horticulture, and fruit growing; particularly for women. Sheep and dairy farming was not associated with any increased risk of NHL. Meat processors had an elevated risk, as did heavy truck drivers, workers employed in metal product manufacturing and cleaning. After semi-Bayes adjustment elevated risks in horticulture, fruit growing and metal product manufacturing and cleaning remained statistically significant and represent the most robust findings of this study.
Mester B et al (2006)	n=710 male and female patients with malignant lymphoma. 18-80 years. Germany. N=710 controls.	Identifying occupations suspected to be associated with malignant lymphoma and to generate new hypotheses.	Multi centre, population based case control study. Odds ratios and 95% confidence intervals for major occupations and industries were calculated using logistic regression analysis, adjusted for smoking (in pack years) and alcohol consumption. Patients with specific lymphoma sub entities were additionally compared with the entire control group using unconditional logistic regression analysis.	The authors observed an increased lymphoma risk among architects, maids, farmers, glass formers and construction workers. Follicular lymphoma showed highly significant risk increases for several occupational groups, including veterinary workers. Multiple myeloma showed a particularly pronounced risk increase for farmers as well as for agricultural and animal husbandry workers.
Mills PY (2003)	n=222 newly diagnosed prostate cancer cases (1999) and 1110 age-matched controls.USA	Risk of prostate cancer and type of crops and commodities cultivated.	Nested case control study of prostate cancer within a large cohort of predominantly Hispanic labour union in California, the United Farm Workers of America. Electronic record linkage between the union register and California Cancer Registry for the years 1988-1999. Age matched controls were selected randomly from the remainder of the cancer cohort.	It was concluded that Hispanic farm workers with relatively high exposure to organochlorine pesticides (lindane and heptachlor), organophosphate pesticides (dichlovos), fumigants (methyl bromide), or triazine herbicides (simazine) experienced elevated risk of prostate cancer compared to workers with lower levels of exposure.
Ruder AW et al (2004)	n=457 glioma cases; and n=648 population-based controls. Iowa,	Farm pesticide exposure and glioma risk.	Multiple logistic regressions were used to control for farm residence, age, age group, education, and exposure to other pesticides.	No positive association of farm pesticide exposure and glioma were found. Other farm exposures may explain the excess brain cancer risk amongst farmers.

	Michigan, Minnosota and Wisconsin			
Samanic CR et al (2006)	n=41 969 applicators, n=22,036 had used dicamba, USA.	Cancer incidence among pesticide applicators exposed to dicamba.	Exposure information through self-administered questionnaire completed 1993-1997 (AHS)	Although associations between exposure and lung and colon cancer were observed, no clear evidence for an association between dicamba exposure and cancer risk was found.
Windsor et al (2005)	Self inoculation with Gudair vaccine	Injuries resulting from self-inoculation.		Increased risks of NHL, HD, multiple myeloma, and leukemia were associated with occupations that involved animal exposure. Regional differences in risk imply that the risks may be associated with exposure to specific livestock or farming practices. These associations may however be confounded by other farming related exposures, such as pesticides. Further exploration necessary.
Van Maele-Fabry GW (2004)	1966-2003, meta analysis of 22 studies	Determining a possible relationship of cancer of the prostate with pesticide exposure.	Substantial heterogeniety of rate ratios existed between the different studies. The major source of heterogeniety was identified as geographic location. Increased meta-rate ratios from Europe and North America.	The increased meta-rate ratio for prostate cancer in pesticide applicators provides additional evidence for a possible relationship between pesticide exposure and prostate cancer. Homogeniety between individual rate ratios, after they were regrouped geographically tends to increase the consistency of the association. However, overall insufficient exposure information from individual studies precludes firm conclusions.
Waddell BZ et al (2001)	n=748 cases of Hodgkin's Lymphoma and n= 2236 population based controls.USA.	Evaluate the relationship between the use of organophosphate pesticides and non-Hodgkin's Lymphoma (NHL) among white male farmers.	Telephone or in person interviews were utilised to obtain data on the use of pesticides. Odds ratios adjusted for age, state of residence, and respondent status, as well as other pesticide use where appropriate were estimated by logistic regression.	Associations were found between the risk of NHL and several groupings and specific orgnaophosphate pesticides, larger risks from proxy respondents complicate the interpretation. Associations, however, between reported use of diazinon and NHL, particularly diffuse and small lymphocytic lymphoma, among subjects providing direct interviews are not easily discounted.

Zheng TZ et al (2001)	n=985 white male subjects and n= 2895 control subjects	Risk of non-Hodgkin lymphoma (NHL) from carbamate insecticide use among farmers	Unconditional logistic regression was used to estimate the association and control confounding.	Compared with non-farmers, farmers had used carbamagte insecticide had between a 30%-50% increased risk of non-Hodgkin's Lymphoma. Among farmers using Sevin the risk of NHL was limited to those who personally handled the product, those who first used the product for > or = 20 years before their disease diagnosis, and those who used the product for a longer period. The results suggest an increased risk of NHL associated with carbamate pesticide use, particularly Sevin.
mortality and pesticides respiratory conditions				
Golec MS et al (2003)	n=47 Thyme farmers and n= 63 urban dwellers in eastern Poland.	Exposure to thyme dust and respiratory disorders.	Medical examinations were performed on the farmers and non-farmers. The examinations included an interview concerning the occurrence of respiratory disorders, work-related symptoms, physical examination, lung function tests, skin prick tests with four microbial allergens and agar-gel precipitation tests with 12 antigens.	Thyme farmers engaged in threshing this herb have elevated occupational risk - a high incidence of work-related symptoms and common occurrence of positive skin and precipitin reactions to bacterial and fungal allergens associated with organic dust.
Senthilselvan AC et al (2007)	n=374 swine farmers (240 men and 134 women) and n=411 non-farming control subjects (184 men and 227 women)	Respiratory health of male and female workers employed full time in large-scale intensive swine operations in Saskatchewan.	Cross sectional study of male and female workers employed full time and non-farming control subjects. Controlled for age and smoking.	Male and female workers were more likely to have chronic and usual cough, and chronic and usual phlegm in comparison to male and female non-farming control subjects. The risks of these symptoms were greater in female workers. No observed increased risks for asthma or asthma like symptoms among female workers. male workers had increased risk of shortness of breath in comparison with nonfarm control males. Swine workers had increased risk of chronic and usual bronchitis-like symptoms. Female workers appear to be at greater risk of these symptoms.

Whyte RT (2002)	n=12 stockmen working in barn systems	Occupational exposure to inhalable dust and ammonia for poultry stockmen working in barn systems	Exposures were measured and compared with established limits for occupational exposure	The individual values of dust exposure for 4 of the 12 stockmen exceeded the occupational exposure standard (OES) of 10.0mg/m3 for inhalable dust; whereas that of all of the individual cage stockmen did not. The mean ammonia exposure experienced by poultry stockmen working in barn systems was 14ppm (11ppm, time-weighted average), for the complete working day. None of the individual values of ammonia exposures for both barn and cage system stockmen exceeded the OESs of 25ppm, although the short term limit of 35ppm for 15 minutes was exceeded on a number of occasions. Current methods for assessing the combined effects of dust and ammonia indicated that 8 of the 12 barn stockmen were at risk compared with 1 of the 8 cage system stockmen.
cardiovascular disease **health status** **mental health**				
Beseler CS et al (2006)	n=29 074 female spouses of private pesticide applicators. AHS study 1993-1997.	Association between depression and pesticide exposure among women.	Cases were those women who had physician diagnosed depression requiring medication. Lifetime pesticide use was categorised as never mixed/applied pesticides, low exposure (up to 225 days), high exposure (>225days); and a history of diagnosed pesticide poisoning. Results adjusted for age, state, race, off-farm work, alcohol, cigarette smoking, physician visits, and solvent exposure.	Depression was significantly associated with a history of pesticide poisoning. Pesticide poisoning may contribute to risk of depression.

Booth N et al (2000)	Cases n= 63 suicides farmers; 63 controls (suicides non-farmers)	Suicide and contact with primary or mental health services	Retrospective case-control design compared male farmers with an age, sex matched control group. Cases where suicide was an open verdict (Exeter Health District) between 1979-1994.	Farmers represent 1% of suicides in England and Wales. There were no significant differences between farmers and controls for the numbers in contact with their general practitioner or mental health services in the three months before death. There may be some differences in health seeking behaviour between the two groups; as over 30% of farmers presented with exclusively physical symptoms. Farmers were more likely to use firearms (42% compared to 11% controls) and significantly less likely to leave a note (21% farmers, 41% controls).
Cross-sectional studies				
Cancers				
Pesticides				
Beseler CSL (2006)	Survey in 8 county area - Colarado.	The relationship between safety practices, neurological symptoms and pesticide poisoning	Cross sectional survey of farmers and their spouses in eight counties in northeastern Colorado. Multivariate logistic regression models were used to determine associations between safety practices, neurological symptoms and pesticide poisoning.	The associations between safety practices and neurological symptoms (difficulty concentrating, feeling irritable, memory difficulties, trouble reading) were increased in the presence of pesticide poisoning. Failure to engage in safety practices were neurological symptoms.
Snyder et al (2003)	N=405	The relationship between agricultural environments and olfactory dysfunction	Cross sectional survey of 405 individuals assessing agricultural exposures, health status and olfactory history. Also completed a scratch and sniff 12 item odor identification test.	Farming is not associated with olfactory loss. However, certain groups of farmers had inflammatory-type reactions who appeared to be susceptible to olfactory loss.

Mortality and Pesticides Neurological symptoms and pesticides				
Kamel FE et al (2007)	n=18 782 Caucasian, male, pesticide applicators. Iowa and North Carolina (AHS)	Exposure to pesticides and neurotoxicity.	Cross sectional survey of pesticide applicators. Provided information on pesticide use and 23 neurologic symptoms typically associated with pesticide toxication.	Increased risk of experiencing symptoms was associated with cumulative pesticide use, personally mixing or applying pesticides, pesticide related medical care, diagnosed pesticide poisoning and events involving high personal pesticide exposure. Greatest risk with use of organophosphate and organochlorine insecticides. Groups of symptoms affecting: cognition, autonomic and motor function and vision were associated with pesticide exposure. Neurologic symptoms are associated with cumulative exposure to moderate levels of organophosphate and organochlorine insecticides, regardless of recent exposure history of poisoning.
A Pilkington et al (2001)	n=612 sheep dipping farmers, n=53 farmers with no sheep dipping experience and 107 ceramic workers.	Hypothesis that chronic low level exposure organophosphates (OPs) in sheep dips is related to clinically detectable measures of polyneuropathy.	Adjusted for confounders.	The findings showed a strong association between exposure to OP concentrate and neurological symptoms, but a less consistent association with sensory thresholds. There was only weak evidence of a chronic effect of low dose cumulative exposure to Ops. Long term health effects may occur in a least some sheep dippers exposed to OPs over a working lifetime. The mechanisms for this remain unclear.
Respiratory conditions				
Chattopadhyay BD et al (2007)	n=316, in summer (n=136) and in winter (n=180)	Evaluate the fungal spore concentration in summer and winter seasons and the pulmonary function status of the workers.	In summer and in winter air sampling was done to measure airborne fungal spore concentration inside the godowns by Rotorod sampler. UK.Aspergilla, Alternaria, Drechslera, Epicoccum, Nigrospora, and Periconia were all common and found in higher concentrations in the winter. Respiratory functional status was assessed among	Restrictive, obstructive and combined types of respiratory impairments were noticed among the workers. Presence of different spores in varying concentration in the working atmosphere may be responsible for the post shift decrement of PFT, allergic symptoms, high lgE level and respiratory impairments among the workers.

			workers in summer and winter. Age, height and weight of workers similar.	
Chatzi L et al (2006)	n=120 grape farmers and n= 100 controls in Northern Crete	Association of allergic rhinitis with use of pesticides among grape farmers in Crete.	Cross sectional study. Protocol consisted of a questionnaire, skin prick tests for 16 common allergens, measurement of specific IgE antibodies against 8 allergens, and spirometry before and after bronchodilatation.	Occupational exposure to multiple agricultural chemicals could be related to allergic rhinitis in grape farmers.
Downs SH et al (2002)	n=1500 children aged 2-7 years from two rural towns, Australia	Investigate whether having lived on a farm as a child in Australia is associated with a lower risk of allergic diseases.	Cross sectional study of children aged 2-7 years from two towns (Wagga Wagga and Mooree in a crop farming region). Parental responses to a questionnaire and skin prick tests for atopy from the children.	Having lived on a farm in Australia can confer protection against atopy in children. Further studies are needed to identify possible mechanisms associated with farm animals or to establish whether this protective effect is explained by other related exposures.
Danuser BW et al (2001)	n=1 542 Swiss farmers	Prevalence and risk factors of self-reported asthma, symptoms of chronic bronchitis, hay fever, and work related respiratory symptoms. (Swiss population study, SAPALDIA-Study)	Farmers divvied into seven groups according to the time farmers spent in different animal confinement buildings. Multivariate analysis was performed with the methods of binary and multivariate logistic regression adjusted for age and smoking habits.	This study demonstrated that agricultural work in Switzerland is associated with an elevated risk for reporting symptoms of chronic bronchitis and chronic phlegm compared with the general Swiss population. Occupational disorders - hours spent in animal confinements is the exposure-response relationship.
Eduard WD et al (2004)	n=2169. Norway	The prevalence of asthma in farmers with different exposure levels to microbial agents and irritant gases is compared.	Atopy was defined as a positive response to multiple radioallergosorbent tests (RAST) with a panel of 10 common respiratory allergens, and asthma was ascertained by a questionnaire using a stratified sample (n=2169) of a farming population in south-east Norway.	Exposure to endotoxins and fungal spores appears to have a protective effect on atopic asthma but may induce non-atopic asthma in farmers.

Monso, EM et al (2000)	n=4 793 crop farmers, Europe	Crop farming as a risk factor for respiratory symptoms of obstructive lung disease assessed.	Questionnaire on respiratory symptoms and occupation was administered to determine prevalence's, roles of certain crops as risk factors for respiratory symptoms assessed through logistic regression modelling.	Concluded that flower and oil plant production is associated with an increased risk of respiratory symptoms in European crop farmers.
Monso EM et al (2004)	n=105 European farmers	Determining the characteristics and risk factors for chronic obstructive pulmonary disease (COPD) in never-smoking European farmers working inside animal confinement buildings	Cross sectional study assessing lung function and air contaminants. Dose-response relationships were assessed using logistic regression models.	Chronic obstructive pulmonary disease (COPD) in never smoking animal farmers working inside confinement buildings is related to indoor dust exposure and may become severe.
Radon KD et al (2001)	n=6 156 animal farmers, Europe	Airway symptoms in different types of animal farmers (cattle, pigs, poultry and sheep) compared to prevalence in general population.	Animal farmers in Denmark, Germany, Switzerland and Spain completed a questionnaire on respiratory symptoms and farming characteristics 1995-1997. This was compared with the results of the European Community Respiratory Health Survey (ECRHS) obtained in the same regions.	Prevalence of wheezing, shortness of breath, asthma and nasal allergies was significantly lower among all farmers in the 20-44 yrs age group than among the general population. Nasal allergies were associated with the development of chronic phlegm. The prevalence of bringing up phlegm in winter among farmers was significantly higher than in the general population. The study supports the hypothesis that farming could be negatively related to allergic diseases.
Talini DM et al (2003)	n=461 agricultural workers, Tuscany	Prevalence of respiratory symptoms in agricultural workers and occupational risk factors.	Cross sectional study of workers from two different areas in Tuscany. Participants responded to a respiratory questionnaire, pulmonary function test and skin prick tests. Occupational risk factors were assessed in response to questions related to 11 specific tasks, most of them related to cow-shed works.	Symptoms of chronic bronchitis were frequent in this population of farmers in Middle Italy. Tasks in the cow-shed are a specific occupational risk factor in respiratory disorders.

Monso EM (2003)	n=1 839 Californian farmers and n= 7,188 European farmers, 1993-1997.	Respiratory symptoms, farm characteristics and risk factors	Respiratory symptoms and farming characteristics were assessed by questionnaire and risk factors associated with symptoms using logistic regression.	Respiratory symptoms were associated with poultry and rabbit farming, flower growing and the cultivation of grain and oil plants. Working in Europe was a statistically significant risk factor for chronic bronchitis and toxic pneumonitis. Chronic bronchitis was related to toxic pneumonitis, work inside confinement buildings and greenhouses. Chronic bronchitis and toxic penumonitis are highly prevalent in European farmers and are mainly attributable to indoor work.
Fertility				
Sallmen et al (2006)	n=2112 1993-1997. Couples, wife < 40 years.	Solvent exposure and sub fertility among families of male licensed pesticide applications (AHS cohort)	28% of couples were defined as sub fertile. Adjusted sub fertility odds ratios (OR) for exposure to solvents were calculated with logistic regression.	Solvents may impair fertility of either gender, though the evidence for female effects is stronger than for male effects.
Osteoarthritis/musculoskeletal				
Rossignol M (2003)	n=10 412 patients in France	Occupational prevalence and risk of osteoarthritis	Nation-wide cross-sectional survey of 10 412 patients in France, their functional and work limitations.	Results contribute to mounting evidence that OA is potentially aetiologically linked to occupation. Agricultural workers showed a significant excess prevalence in OA, with an observed to expected (O/E) ratio of 1.7 in women and 2.3 in men. Total work disability was highest among blue collar workers and partial disability among agricultural workers.
Health				
Firth H et al (2001)	n=586 individuals from 286 farms. Southland, New Zealand.	Health of farmers in Southland	Cross-sectional study of a random sample of farmers.	High levels of injury, low back pain was common, noise-induced hearing loss prevalent among men. Low levels of asthma, 19.3% of male farmers were obese. Prevalence of alcohol use disorder maong men aged 15-24yrs was 57.4% and 39.0% among farm workers. 32% of men 15-24 years smoked, with 35.6% of farm workers being smokers.

Mental Health

Beseler CSL (2006)	n=761 farmers, Colorado.	pesticide poisoning and depressive symptoms among farm residents	Cross sectional survey of farmers and their spouses conducted in Colarado	Exposure to pesticides at a high enough concentration to cause self reported poisoning symptoms was associated with high depressive symptoms independently of other known risk factors for depression among farm residents.
Booth NJL (2000)	n=??? Farmers in South West England	Occupational stress, anxiety and depression	Postal survey of farmers and spouses.	35% of respondents scored positively on the General Health Questionnaire (GHQ) with female respondents showing significantly higher scores than males. A significant proportion of respondents showed elevated levels of anxiety and depression - measured by the Hospital Anxiety and Depression Scale (HAD). Most common sources of perceived stress were coping with new legislation, paper work and media criticism.
Carruth AKL et al (2002)	n=657 women 18 years +, southeast Louisiana.	Farm women and depressive symptoms.	Factors predictive of depressive symptoms in adjusted logistic regression included those who experienced poor health, perceive hazards associated with farming, experience recent farm injuries and engage in farming over a long period of time.	A multitude of responsibilities, environmental and social influences place farm women at high risk for depressive symptoms.
Firth H et al (2007)	n=1015 farmers, New Zealand	Stress in New Zealand Farmers	Cross sectional survey of 1015 New Zealand farmers.	
Peden AR et al (2005)	n=299 14-18 year olds	Depressive symptoms in adolescents living in rural USA		

Sanne BM et al (2004)	n=17 295, of which n=917 were farmers	Examine anxiety and depression in farmers and non-farmers	Levels of anxiety and depression were assessed by the Hospital Anxiety and Depression Scale (HADS-A and HADS-D, respectively). Self reporting on work related factors, demographics, lifestyle and somatic health problems.	Farmers had higher levels and prevalence's of depression particularly male farmers, who also had higher anxiety levels. For men, farmers reported longer working hours, lower income, higher psychological job demands and less decision latitude compared with non-farmers. Farmers had physically heavier work and lower levels of education. The differences were greatest between full-time farmers and non-farmers. Farming is associated with increased levels of anxiety and increased levels and prevalence's of depression.
Stallones LB (2006)	n=761 individuals, Colorado	Association between pesticide poisoning and depressive symptoms among farm residents	cross sectional survey of farmers and their spouses in an eight county area in northeastern Colorado	Exposure to pesticides at high enough concentration to cause self reported poisoning symptoms was associated with high depressive symptoms independently of other know risk factors for depression among farm residents.
Prevalence Surveys **Cancers** **Pesticides**				
Tahmaz NS et al (2003)	n=206, United Kingdom	Association of exposure to organophosphates and the development of chronic fatigue	Two questionnaires; the first identifying the history of exposure and then their exposure was reconstructed using a metric specifically developed for this purpose. The second questionnaire identified whether the subject had CF when they reported to the surveillance scheme and or when the participated in the survey.	Higher CF scores were associated with higher exposure to organophosphate pesticides. Further research is necessary.

Respiratory conditions

Lamprecht BS et al (2007)	n=2 200 adults aged 40 yrs and over	Burden of obstructive lung disease and occupational exposure	Gender stratified, population-based sample of 2,200 adults aged 40 years and over. Pre- and post bronchodilator spirometry, information on smoking, occupation, and reported respiratory disease. Non-reversible airways obstruction was defined as a post-bronchodilator forced expiratory volume (FEV (1)/forced vital capacity (FVC) <0.70. Farming defined as ever having worked in farming for 3 months or longer.	22.9% of respondents reported farming. The prevalence of non-reversible airways obstruction amongst these participants was 30.2% Farming was significantly associated with airways obstruction even after adjustments were made for age, gender, and smoking. The risk for non-reversible airways obstruction attributable to farming was 7.7%.
Melbostad EE (2001)	n=8 482 farmers and spouses	Exposure to organic dust and work-related symptoms in farmers	Survey of 8 482 farmers and spouses, task related respiratory and eye symptoms were recorded by questionnaire. Personal exposure to total dust, fungal spores, bacteria, endotoxins, and ammonia during 12 different tasks was measured in a random sample of 127 farms (288 measurements).	Work related symptoms are common in farmers and are associated with exposure to total dust, fungal spores, and endotoxins.
Radon KG et al (2000)	n=100 swine producers	Evaluation of characteristics of pig houses that are associated with the development of respiratory morbidity in 100 swine producers with work related respiratory symptoms	Questionnaire for farm characteristics and lung function was assessed immediately before and after feeding the pigs. Exposure to dust and endotoxins were determined by personal sampling.	Among symptomatic pig farmers, those with higher numbers of pigs and longer duration of employment are at highest risk for developing functional impairment.
Radon K et al (2001)	n=36 poultry farmers; n= 40 pig farmers	Relation between spirometric findings and farming characteristics and variables of exposure to organic dust	Farmers were chosen randomly and were assessed over a working day.	Ventilation of the animal house and temperature might influence respiratory morbidity in farmers.

		measured during a working day.		
Radon KS et al (2007)	n=6 937, Germany. Adults (18-45 years)	Environmental exposure to concentrated animal feeding operations and respiratory health.	Sample from four rural towns in Germany with a high density of confined animal feeding operations.	Confined animal feeding operations may contribute to the burden of respiratory disease among their neighbours.
Radon Kw et al (2003)	n=325 sheep breeders, Germany	Prevalence of respiratory symptoms in sheep breeders and potential work related risk factors.	Mailed questionnaire to all sheep breeders in two regions in Germany. Prevalence's compared to the results of the European Farmers Study.	Sheep breeders might be at risk of the development of respiratory symptoms. These symptoms may be associated with work intensity and chemical exposure during work. More research needed.
Schenker MB et al (2005)	n=1 947 Californian farmers	Dust exposure in agriculture and respiratory symptoms.	Population based survey, collecting information on respiratory symptoms, occupational and personal exposures. Logistic regression models used to assess associations between dust and respiratory symptoms.	Occupational dust exposure among Californian farmers, only one third of whom tended animals, was independently associated with chronic respiratory symptoms.
Sprince NL et al (2000)	n=385 farmers	Risk for airways disease resulting from exposures which include organic agents and chemicals on the farm.	A stratified two stage cluster sample, providing a representative farmer sample from the state. Questionnaire recording reparatory symptoms, smoking, and exposure information. Logistic regression analysis adjusted for age and smoking.	The association between insecticide application to livestock and symptoms of airways disease is a new finding that could lead to further study of specific airway responses and exposures associated with this practice. Associations between respiratory symptoms and conventional vertical silos in farm buildings.
Smit LA et al (2007)	n=1798, The Netherlands	Effects of organic farming on respiratory health	Compared hay fever and asthma like symptoms in organic and conventional farmers and to assess associations between current and childhood farm exposures and respiratory health effects by conducting a survey.	Produced evidence that a farm childhood in combination with current livestock farming protects against allergic disorders. This effect was found for both organic and conventional farmers.

Cardiovascular disease				
health status				
Alderete EV et al (2000)	n=1001 18-59 years, Indian vs non-Indian Mexican farm workers and Mexican migrant farm workers	Risk factors for psychiatric disorders among Mexican farm workers in California	A modified version of the Composite International Diagnostic Interview was used for case ascertainment. Effects of socio-demographic and acculturation factors on lifetime psychiatric disorders were tested.	Life time prevalence of any psychiatric disorder was lower from migrants than for Mexican Americans and for the US population as a whole. High acculturation and primary US residence increased the likelihood of life-time psychiatric disorders. The results underscore the risk posed by cultural adjustment problems the potential from progressive deterioration of this population's mental health, and the need for culturally appropriate mental health services.
De Armond SE et al (2006)	n=709 farm operators and spouses, northeastern Colorado	Depression and somatic symptoms	Exploratory and confirmatory factor analyses were conducted on the symptom inventory and suggested two factor structure (psychological, physical).	Both psychological and physical symptoms significantly correlated with depression; psychological factor was more strongly correlated. Only minor differences between genders.
De Armond SE et al (2006)	n=709 farm operators and spouses, northeastern Colorado	Depression and somatic symptoms	Exploratory and confirmatory factor analyses were conducted on the symptom inventory and suggested two factor structure (psychological, physical).	Both psychological and physical symptoms significantly correlated with depression; psychological factor was more strongly correlated. Only minor differences between genders.
mental health				
Judd F et al (2006)	n=371 farmers and n= 380 non-farming rural residents. Australia	Rate of mental health problems amongst farmers compared with non-farmer rural residents and possible associations with increased rates of suicide amongst farmers.	Self reported questionnaire and semi structured interviews with 32 farmers.	The elevated rate of suicide amongst farmers does not appear to be explained by an elevated rate of mental health problems. Individual personality, gender and community attitudes that limit a person's ability to acknowledge or talk about mental health problems and seek help may be significant risk factors for suicide in farmers.

Peden AR et al (2005)	n=299 14-18 year old rural adolescents	Examine prevalence of depressive symptoms amongst rural adolescents and identify related social and environmental variables.	Surveyed for social and environmental information and completion of the Center for Epidemiological Studies Depression Scale (CES-D), as well as scales to assess the number of major life events in the last year, active coping use and family closeness.	The prevalence of high level depressive symptoms in this sample was 34%. Interventions to identify and prevent depressive symptoms in rural adolescents are needed.
Scarth RD et al (2000)	n=385 Iowa farmers and n= 470 Colarado farmers	Comparison of risk factors and depressive symptoms	Evaluated for depression using the CES-D scale.	Although Iowa farmers had 1.74 times higher level of depression symptoms than the Colarado farmers, this difference was not significant after adjusting for higher levels of risk amongst Iowa farmers. i.e. Iowa farmers had almost twice the frequency of substantial income decline.
Solomon C et al (2007)	n=9844 men, England and Wales	Prevalence and pattern of neuropsychiatric symptoms in past users of sheep dip and other pesticides	Postal survey of men born between 1933 and 1977 and resident in three rural areas in England and Wales. Lifetime work history of work with pesticides, neurological symptoms in the past month, current mental health and tendency to be troubled by non-neurological somatic symptoms. Risk factors assessed by modified Cox Regression.	Neurological symptoms are more common in men who have worked with sheep dip. Past use of pesticides was not associated with current anxiety or depression.
musculoskeletal disorders				
Case series				
Mental Health				
Judd et al (2006)	n=371 farmers and 380 rural non-farmers	Farming occupation	Mental health problems. Models adjusted for each other.	Farmers found to not experience higher levels of mental health problems compared to non-farmers. Farmers more psychologically healthy, higher physical health state, lower levels of disability and distress associated with mental health problems compared with rural non-farmers. Significant difference in personality traits found that may buffer farmers from distress.

Routine Data				
Cancer				
Clary TR (2003)	1989-1996 deaths from pancreatic cancer, USA. Mortality data.	The relationship between organochlorine pesticides and the occurrence of pancreatic cancers	Employed a morality odds ratio design to compare deaths from pancreatic cancer (1989-1996) with a random sample of non-pancreatic cancer deaths. Pesticide data and residential use data was used. Logistic regression used to estimate the effect of pesticide applications by ZIP code, controlling for potential confounders.	The study suggested increased pancreatic cancer mortality among long term residents in areas of high application rates of 1,3-d (an EPA-classified probably human carcinogen), captafol, pentacholoronitrobenzene (PCNB) and dieldrin.
Lee EB et al (2002)	1984-1993; industry and occupation coded mortality data. USA	Evaluation of mortality patterns among crop and livestock farmers.	Cause-specific proportionate mortality ratios (PMRs) were calculated using a National Institute for Occupational Safety and Health (NIOSH) program designed to calculate sex and race specific PMRs for industries and occupations in population-based data.	Among White Male livestock farmers significantly higher mortality from cancer of the pancreas, prostate and brain, non-Hodgkin's lymphoma, multiple lymphoma, acute and chronic lymphoid leukemia, and Parkinson's disease. White male crop farmers showed significantly higher mortality risk of cancer of the lip, skin, multiple myeloma, and chronic lymphoid leukemia. The disease trends suggest that livestock farmers might be exposed to more carcinogens or agricultural chemicals than crop farmers.
t Mannetje A et al (2008)	New Zealand cancer registry, 2003-2004. n=291 incidence cases.	Assess whether farmers and meatworkers are at increased risk of NHL.	291 incident cases of NHL (age 25-70 years) and 471 population controls, interviewed face to face. Demographic data and full occupational history collected. Relative risk of NHL associated with ever been employed in particular industries and occupations calculated using logistic regression adjusting for age, sex, smoking, ethnicity and socioeconomic status. Estimates subsequently semi-Bayes adjusted to account for the large numbers of occupations and industries being considered.	The study confirmed that crop farmers and meat processing workers remain high risk occupations for NHL in New Zealand, and has identified several other occupations and industries of high NHL risk that merit further study.

McDuffie H et al (2007)	Cancer registry 1979-2000, Saskatchewan, Canada.	Incidence rates of testicular cancer and the role of agricultural exposure.	Comparing farmers with non-farmers. Used logistic regression analyses with adjustment for relevant variables.	Farmers were significantly more likely than non-farmers to be diagnosed at stage 2 or higher [1.76 (1.00-3.10)]. Based on this data the significant predictors of being diagnosed with stage 2 and higher are: presence on nonseminoma, < or =26 years old, and farming as an occupation.
Reynolds PH et al (2005)	1988-1997 Cancer registry, California	Evaluate whether California breast cancer rates were elevated in areas with recent high agricultural pesticide use.	Identified population-based invasive breast cancer cases from the California Cancer Registry for 1988-1997. Used California's pesticide use reporting data to select pesticides for analysis based on use volume, carcinogenic potential, and exposure potential. Census data was used to derive age and race specific population counts for the time period of interest. GIS used to aggregate cases, population counts and pesticide use data for all block groups in the state. Rate ratios and 95% confidence intervals using Poisson Regression models, adjusting for age, race/ethnicity, neighborhood socioeconomic status and urbanization.	The results from this study provide no evidence that these women living in areas of recent, high agricultural pesticide use experience higher rates of breast cancer.
Reynolds PH et al (2005)	Cancer data base 1988-1994	Evaluate whether the rates of lymphoproliferative malignancies among children are elevated in areas of intensive agricultural pesticide use in the state of California in the United States.	Study included all newly diagnosed, statewide cases of childhood lymphoma and acute lymphoblastic leukemia in 1988-1994 among children <15 years.	The generally null results from this study, which systematically examined the risk relationships for residential proximity to agricultural pesticide use stand in contrast to existing epidemiological literature which suggests elevated childhood cancer risks from reported household pesticide use. The differences may be due to different chemical agents, or different exposures: indoor and outdoor, or both. More work is needed to better characterise the exposure potential for children to these agents.
Rodvall Y et al (2003)	Swedish cancer registry and records of male pesticide	Explore cancer risk from date of birth until 1994 in children, born 1958 or later, of	Records of male pesticide applicators registered 1965-76 were linked to the Multigeneration Register. The records of their offspring were then linked to the	None of the apriori hypotheses of increased risk of tumors of the nervous system, kidney cancer, leukemia, lymphoma, soft tissue sarcoma, and testicular cancer in children of male pesticide applicators could be

	applicators. 1965-1976.	Swedish male pesticide applicators.	Swedish Cancer Registry and the Cause of Death Register.	confirmed.
Respiratory Conditions				
McDonald JC et al (2005)	National surveillance data, United Kingdom. 1992-2001	Summarise incidence rates and epidemiological characteristics of new cases of work related respiratory disease; particular attention to occupation, industry, causal agents for asthma, inhalation accidents and allergic alveiolitis. 1992-2001	Cases reported 1992-2001 were analysed by age, sex, cause, occupation and industry with incidence rates calculated against appropriate denominators.	The reported incidence of new cases of acute respiratory illness caused by work remains substantial.

Arif AA et al (2002)	national health and nutrition survey, 1988-1994, USA.	To estimate the prevalence of work related wheezing in United States workers and to identify high risk industries and determine the population attributable risk of work related asthma and work related wheezing.	National health and nutrition survey (1988-1994) was analysed to determine the prevalence of work related asthma and wheezing and identify industries at risk amongst US workers aged 20 and over. Work related asthma was defined as affirmative response to questions on self reported physician diagnosed asthma and work related symptoms of rhinitis, conjunctivitis, and asthma. Work related wheezing defined as affirmative response to questions on self reported wheezing or whistling in the chest in the previous 12 months and work related symptoms of rhinitis, conjunctivitis, and asthma.	The main industries identified at risk of work related asthma and wheeze were the entertainment industry, **agriculture,** forestry and fishing, construction, electrical machinery, repair services and lodging places. The population attributable risk for work related asthma was 36.5% and work related wheezing was 28.5%.
Osteoarthritis				
Rossignol M et al (2005)	Patients presenting with osteoarthritis of the knee, hip or hand. France.	To identify occupations with excess prevalence of osteoarthritis of the knee, hip and hand. Identify biomechanical stresses and severity.	Nationwide survey.	Occupations with the greatest prevalence rate ratio were female cleaners, women in the clothing industry, male masons and other construction workers and agriculture male and female workers. Early onset seen in heavier labour jobs with first symptoms before the age of 50 years.
Cardiovascular Disease				
Sjogren B et al (2003)	Swedish National Censuses of 1970 and 1990, male and female livestock and agricultural workers, followed until 1995.	Compare the occurrence of ischemic heart disease (IHD) among male and female livestock and agricultural workers in Sweden.	IHD mortality of livestock and agricultural workers compared with gainfully employed men and women of Sweden. Information on smoking gained from a previous national survey.	The study suggested a slightly increased risk for IHD among both male and female livestock workers, which may be a result of organic dust exposure.

Mental Health

Page A et al (2007)	Suicide data set. Australia	Investigating changes in Australian urban-rural suicide rates. 1979-2003	Suicide data were stratified for the period 1979-2003 by metropolitan, rural and remote areas and examined across five quinquennia, centred on each Australian census from 1981-2001. Rates were adjusted for confounding by age, sex, country of birth and the mediating effects of area SES using Poisson Regression Models.	Urban rural differences were statistically significant. The largest urban-rural male suicide differentials for the 25 year study period occurred in the most recent period (1999-2003), in the context of decreasing male suicide rates overall. Increases for males aged 15-24 yrs. (NB increase in remote areas from 38.8 (per 100 000) to 47.9 (a 23% increase).
Page A and Fragar L (2002)	Suicide data set. Australia	Identify and describe suicide data for occupational classifications relating to farm managers and agricultural labourers; 1988-1997, Australia.	921 suicides identified for this period. The majority were amongst farm managers and amongst those 55 years and over. Agricultural labourer suicides were in the younger age groups, with the majority occurring in the 15-39 year age group. Most common methods involved firearms, hanging and motor vehicle exhaust gas. These three methods accounted for 81% of male suicides in this period.	Male farm manager and agricultural labourer suicide rates are higher than male national rates and rates in the wider rural population, particularly in the latter years investigated.
Stark CG et al (2006)	Scottish death records, 1981-1999	Suicide and undetermined death in male farmers and farm workers in Scotland from 1981-1999.	Deaths of men aged 15-74 years from suicide or undetermined cause were identified. 307 in total during this period. The overall rate was 31.4 100 000 per year (95% CI 28.1-35.1)	Availability of firearms appears to contribute to suicide rates. Higher rates of suicide amongst farmers in areas where farming is less common. Suggesting that networks and social supports may be important protective factors.
Simkin SH et al (2003)	Suicide data set. England and Wales 1982-1999	The relation between seasonality and suicide of male farmers.	Seasonal patterns of suicide in farmers and nonfarmers were examined by nonparametric tests and harmonic analysis.	No significant seasonal variation was found for farmers. significant difference in the variation of violent suicides t year. Seasonal variation appears to be diminishing in this

Leptospirosis

Thornley C N et al (2002)	Surveillance and disease notification data, 1990-8. New Zealand	Describing current epidemiology and trends in NZ human letospirosis.	Using descriptive epidemiology of laboratory surveillance and disease notification data, 1990-8.	The incidence of human leptospirosis in New Zealand remains high for a temperate developed country. Incidence was highest amongst meat processing workers, livestock farm workers and forestry related workers. Increasing L. Bourgpetersenlii sv. Ballum case numbers suggest changing transmission patterns via direct or indirect exposure to contaminated water.