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DISSERTATION

A COMPOSITE RISK SCORE SYSTEM FOR PREDICTING AGRICULTURAL INJURY AMONG COLORADO FARMERS

Submitted by Huiyun Xiang

Department of Environmental Health

In partial fulfillment of the requirements for the

Degree of Doctor of Philosophy

Colorado State University

Fort Collins, Colorado

Fall 1999

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Colorado State University

November 3, 1999

WE HEREBY RECOMMEND THAT THE DISSERTATION PREPARED UNDER OUR SUPERVISION BY HUIYUN XIANG ENTITLED *A COMPOSITE RISK SCORE SYSTEM FOR PREDICTING AGRICULTURAL INJURY AMONG COLORADO FARMERS* BE ACCEPTED AS FULFILLING IN PART REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY.

Committee on Graduate Work

Advisor

Department Head

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ABSTRACT OF DISSERTATION

A COMPOSITE RISK SCORE SYSTEM FOR PREDICTING AGRICULTURAL INJURY AMONG COLORADO FARMERS

Objective This study aims to describe patterns of injury among Colorado farmers, identify potential risk factors, and develop a simple injury risk score system to predict the probability of agricultural work-related injuries. The ultimate goal is to develop a simple tool to identify Colorado farmers with high risk of agricultural work-related injuries.

Methods Data collected by the Colorado Farm Family and Hazard Surveillance project from January 1993 to December 1996 were used. This surveillance project interviewed 872 farmers (470 males and 402 females) on 485 Colorado farms in a statewide telephone survey in 1993 and 761 farmers (478 males and 283 females) on 478 farms by face-to-face interviews in an eight county area between 1993-1996. Seven hundred forty six out of 872 statewide participants (85.6%) were interviewed again in 1994, and six hundred twenty five out of those 746 participants (83.8%) were interviewed again in 1995. Participants were asked specifically about agricultural injuries which occurred in the previous 12 months, and the potential risk factors were evaluated. Injury risk scores were calculated using information from the logistic regression models estimated from first year statewide data. Then, the predictability of this injury risk score

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system was evaluated using data from the second and third year of the statewide surveys and data from the survey in the eight county area.

Results The agricultural injury rates among farmers interviewed by CFFHHS ranged from 7.4% to 11.5%. The leading causes of agricultural work-related injuries were overexertion (21% - 30%), animals (10% - 25%), falls (11% - 23%), and sharp objects (9% - 20%). Injuries mainly resulted in sprains and strains (30% - 38%), fractures (14% - 20%), and open wounds (5% - 20%). Farm machines caused only 6% - 9% of all agricultural work-related injuries in this study.

It was found that injured farmers were significantly more likely to be: 1) males, 2) young farmers, 3) farmers with farming or ranching as main occupation, 4) farmers involved in animal products, 5) farmers worked 50-149 days per year in off- farm employment, 6) farmers lost sentimental things, 7) those who had legal problems, and 8) farmers with poor health status.

Injury risk scores developed from logistic regression models showed good relationships with observed proportions of agricultural work-related injuries among those Colorado farmers. The final nomogram injury risk worksheet provided a simple tool to identify Colorado farmers with high risk of agricultural injuries.

Conclusions This study demonstrated that a simple injury risk score system, based on demographics of farmers, farming activities, and negative life events, is a reliable and valid tool for predicting risk of agricultural work-related injuries as a continuous phenomenon among Colorado farmers. The good correspondence of results in the cross-validation study also demonstrated that the injury risk score system can provide

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predictive evaluations of work-related injury risk in farmers even when used for different populations in other settings.

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CHAPTER I

INTRODUCTION

The World Health Organization (WHO) predicted that injuries will be responsible for more death, morbidity and disability than all communicable diseases combined by the year 2020 (Murray et al., 1998). Currently, injuries account for one in seven years of potential life lost worldwide, but by 2020, they will account for one in five, with the developing countries bearing the brunt of this increase (Vilardo, 1988; Zwi, 1996; Murray et al., 1998). In the United States, injury morbidity and mortality have been persistent problems (Bonnie et al., 1999). Recent findings indicated that in 1995 alone, injuries were responsible for 147,891 deaths, 2.6 million hospitalizations, and more than 36 million emergency room visits (Fingerhut and Warner, 1997). It has been estimated that injury accounts for 12 % of all medical spending (Miller et al., 1994). Unintentional injuries and violence account for about 30 % of all lost years of productive life before age 65, exceeding losses from heart diseases, cancer, and stroke combined (U.S. DHHS, 1992; Waller, 1994; Bonnie et al., 1999).

In its recent assessment of the injury problem in the United States, the Committee on Injury Prevention and Control at Institute of Medicine (Bonnie et al., 1999) noticed a great disparity between magnitude of the injury problem and paucity of federal financial support for injury-related research (Figure 1.1).

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THE INJURY FIELD

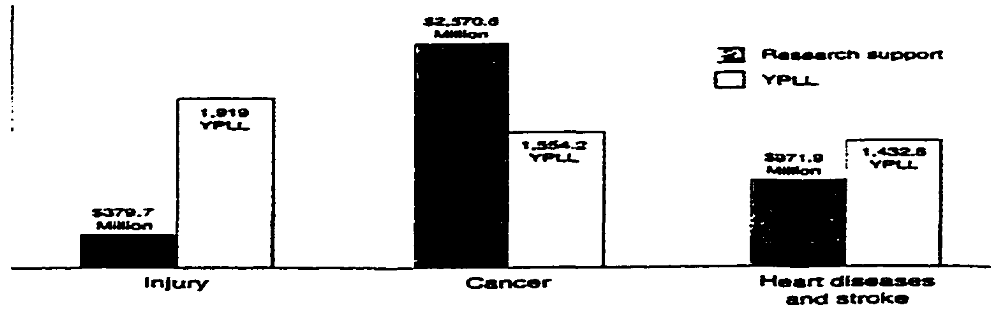

FIGURE 1.1 Years of potential life lost versus the federal research investment. NOTE: Age-adjusted years of potential life lost (YPLL) before age 75 in 1996 was calculated per 100,000 population. Injury includes unintentional injury, homicide, and suicide. The research support for injury is for FY 1995; research support for cancer, heart diseases, and stroke is NIH support for FY 1996. SOURCES: NCIPC (1997); IOM (1998); NCHS (1998).

Compared with efforts targeted toward other major health problems, the federal injury research effort was fragmented and seriously underfunded. This should come as no surprise because, for centuries, human injuries have been regarded either as random and unavoidable occurrences ("accidents" or "acts of God") or as untoward consequences of human malevolence or carelessness (Waller, 1994; Bijur, 1995; Loimer et al., 1996). From this perspective, the main strategies for prevention are prayer and human improvement (Bonnie et al., 1999).

The word "accident" suggests an event that happens without foresight or expectations (Waller, 1994; Bijur, 1995; Loimer et al., 1996). For many generations, injury events have tended to be attributed to human errors or misactions. With the advent of industrialization in the nineteenth century, the environmental risk factors for injury became more discernable, and the challenges of "accident prevention" and industrial

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safety began to receive sustained attention. Railroad, textile, and mining industries began monitoring work-related injuries in the early 1800s (Loimer et al., 1996). Political movements for worker protection developed rapidly first in Europe and, later in the United States, provided social context for the creation of the National Safety Council in the United States in 1913 and the Royal Society for the Prevention of Accidents in England in 1916 (Bonnie et al., 1999). Although interest in and support for safety grew over the course of the twentieth century, systematic scientific inquiry was rare, and injury control and prevention efforts in society were episodic and disconnected. This situation changed dramatically during the 1960s and 1970s when two developments converged to establish the intellectual and social foundation for a new field of research and social action in injury control: (1) a relatively substantial financial investment in injury prevention, and (2) the emergence of injury science as a distinct interdisciplinary field of research within the domain of public health (Baker, 1989; Bonnie et al., 1999).

Injury as a public health problem means that injuries, in aggregate, produce an enormous toll of disability and premature death, draining health care dollars and weakening the nation's productive capacity (Bonnie et al., 1999). Fortunately, the harm of injuries can be reduced or ameliorated by using analytic tools and preventive perspectives of public health. In the past decades, the prevailing opinion in the public health community was that the use of the word "accident" was detrimental to injury control and prevention efforts (Bijur, 1995; Loimer et al., 1996). This is due to connotations of fate, chance, and unpredictability associated with the word. As a result, public health, pediatric, and medical literature over the past decades have increasingly

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replaced the word "accident" with the term "injury", which is neutral with respect to causation, intentionality, and predictability (Bijur, 1995). While decades of research have made it clear that there are seasonal, geographic, epidemic, and demographic variations in the occurrence of injuries, such events as a group are substantially nonrandom and do not occur by chance (Waller, 1985). More and more people agree that while no single injury event - just as no single heart attack - can be predicted with complete accuracy, to a substantial degree its likelihood can be foreseen and even quantitatively predicted for specific populations and circumstances (Waller, 1985; Bijur 1995; Loimer et al., 1996).

Generally speaking, an injury control system consists of three integrated components: prevention, acute care, and rehabilitation (National Highway Traffic Safety Administration, 1994). In the prevention stage, approaches are sought to avert injury. This is accomplished by identifying causes of injuries and targeting those at high risk for different types of injuries, by developing and implementing effective interventions, and by monitoring and evaluating the effectiveness of interventions on populations at risk. The underlying goal of numerous studies in injury prevention research was to: 1) identify high risk populations, 2) determine the causes of injuries, and 3) design intervention programs. The majority of these studies used descriptive and analytic approaches to study risk factors for injuries and to identify high risk individuals based on certain characteristics. Unfortunately, little has been done to combine all of the information regarding those multiple risk factors and create a simple method to assess injury risk for individuals with certain characteristics.

In this dissertation research, a composite injury risk score approach has been

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developed for assessment of injury risk among Colorado farmers. The composite risk score system has been developed for use in epidemiology to combine information contained in a number of risk factors in a way to best evaluate one individual's probability of an adverse outcome. Despite controversy about the accuracy and generali of this method, it is widely used, both by clinicians for predicting the outcome of diseases and by public health professionals for evaluating risk of developing diseases in populations. This dissertation is divided into several chapters. In the literature review chapter, historical development of injury control research, particularly injury control concepts, is reviewed in detail, and approaches to predict injury risk is discussed. The hypothesis and specific objectives of this project are presented in chapter III. The methodology chapter describes step-by-step approaches to develop the proposed composite risk score system and the methods to evaluate this injury risk score system. The results chapter presents injury prediction results among farmers. Finally, the discussion chapter addresses issues regarding development and application of the composite risk score system in thc prediction of injury risk.

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CHAPTER II

LITERATURE REVIEW

2.1 Development of Injury Control Concepts

For many generations, injury events have tended to be attributed to human errors or misactions (Waller, 1994). The word "accident" has a philosophical pedigree and an interesting etymological history (Baker, 1989; Loimer et al., 1996). Aristotle used it first to define nonessential or extrinsic characteristics. According to Aristotle, people and things had substantial and accidental qualities. At the peak of Norman influence around the 14th century, the English world began to use another meaning of the word, the meaning commonly understood today: to happen by chance; a misfortune; an event that happens without foresight or expectation.

So, in everyday conversation, particular kinds of misfortunes are defined as accidents through their ascribed cause or rather, lack of cause. There are two factors that apparently characterize the process by which accidents are seen to occur (Green, 1997). The first is that an accident should be an unmotivated event; neither the victim nor any other agency, human or divine, willed it to happen. In general, no one can be blamed for the occurrence of an accident. It is this feature that distinguishes accidents from willful damage and neglect. Secondly, and following from this, an accident is unpredictable as a unique event. The victim, in an ideal accident, has no previous knowledge of the

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misfortune and can not be held responsible. Although accidents can be mapped through aggregation and examination of their incidence, the occurrence of a particular accident can not be foreseen (Green, 1997).

Why was this orientation so widespread until about the middle 1960s, persisting somewhat even today? Several reasons have been given (Waller, 1994). One reason may be that in the first half of the century, the United States still saw itself as a frontier society with emphasis on individual responsibility for coping with the environment. Another reason lies in the fact that the new field of psychiatry emphasized emotional antecedents to life events. By the 1930s and 1940s, causal concepts of injury spoke of subconscious "accident proneness". The common belief was that what befell individuals was what they really wanted. The third reason involves conceptualization in our data recording system. Most data systems tend to record only a single "cause" of injury. For example, the police and highway personnel would often argue that the previous hundred drivers had not gotten into trouble at a specific crash location, and therefore, the sole reason why this person crashed must be because he or she did something wrong. There are also some evidence that bereft families tried to comfort themselves with the assurance that the event which resulted in a fatal injury was "an accident" (Rosenblatt et al., 1993). And it also has been hypothesized that families who perceived their loved ones' death as having been preventable suffer longer and more intense grief (Bugen, 1977).

With the advent of industrialization in the nineteenth century, environmental risk factors for injury became more discernible, and the challenges of " accident prevention" and injury control began to receive sustained attention. Private industries began

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recording work-related injuries in the early 1800s (Loimer et al., 1996). Political movements for worker protection in Europe and the United States created a social context for creation of the National Safety Council in the United States in 1913 and the Royal Society for the Prevention of Accidents in England in 1916 (Bonnie et al., 1999).

Modern injury science began to take shape as a distinct field in the mid-1960s. Perhaps the key conceptual development was the recognition that patterns of injury distribution and causation could be analyzed using epidemiologic tools of public health and that the etiology of injury included environmental factors and the interaction between human and environmental factors (Bonnie et al., 1999). One of the scientific developments that grew was the field of ergonomics, or human factors. This discipline examines aspects of the environment that affect how people perceive and act in their daily endeavors, as well as individual attributes determined by anatomy, physiology, training, and social constructs that affect people's responses to the environment (Waller, 1994).

When scientists and others tried to study injury in the same manner as one would study infectious diseases, they were puzzled, however, by the seemingly unlimited potential agents of injury - cars, bicycles, stairs, stoves, matches, and alcohol, to mention a few.

This dilemma was resolved by Dr. William Haddon, an engineer and public health physician in the early 1960s (Waller, 1994). Building on the work of other scientists, Haddon described all injury events as attributable to the uncontrolled release of one of five forms of physical energy (kinetic, chemical, thermal, electrical, and radiation). From a preventive or ameliorative standpoint, interventions can be made during three temporal

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phrases in relation to the injury event: (1) a pre-event phase, during which energy becomes uncontrolled; (2) a brief event phase in which uncontrolled energy is transferred to the individual, resulting in injury if energy transfer exceeds the tolerance of the body to absorb it; and (3) a post-event phase, during which attempts can be made to restore homeostasis and repair the damage (Waller, 1994; Bonnie et al., 1999). From this three-phase conceptualization of injury causation, the traditional public health categorization of risk factors and intervention methods could be applied in injury control.

The latest extension of Haddon's work (Haddon and Baker, 1981) provided a matrix that could be used as a tool in developing accident prevention strategies. The classic host -agent- environment interaction was separated more definitely into host, vector or vehicle, physical environment and sociological environment. A time factor was added allowing strategies to be examined before, during and after an injury event. Crossing the time factors by host, vector, physical and sociological environments, yielded twelve different areas in which injury prevention strategies could be employed (Aherin et al., 1992; Bonnie et al., 1999).

2.2 Injury as a Public Health Problem

Previous work by many scientists explicitly recognized that the public health paradigm could be applied to injury control and prevention. Injuries constitute a major public health problem because, in aggregate, they produce such an enormous toll of disability and premature death, draining health care dollars and weakening a nation's

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productive capacity. To say that injury is a public health concerns also means that the harms of injury can be reduced or ameliorated by using analytic tools and the preventive perspectives of public health. Indeed, because the public health paradigm can embrace all etiologic factors bearing on prevention, it has been widely accepted by analysts in all disciplines, even though many of the interventions lie outside the expertise and capacity of public health agencies (Bonnie et al., 1999).

Injury is a major public health problem in the United States considering the following facts in 1995 (Bonnie et al., 1999):

- 59 million episodes of injuries were reported;
- 2.6 million hospital discharges and 37 million emergency department visits were for the treatment of injuries;
- 147,891 individuals died as a result of an injury;
- 77 percent of all deaths and 10 percent of the hospitalizations among 15 to 24-year-olds were caused by injuries;
- 52 percent of all deaths and 17 percent of the hospitalizations among 5- to 15 year-olds were caused by injuries;
- Injury and its consequences accounted for 12 percent of all medical spending and the cost of injury was estimated at $260 billion.

2.2.1 Overall burden of injury: mortality rates

In the United States, 90,402 people died from unintentional injuries (61% of all injury

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fatalities, for a rate of 34.4 deaths per 100,000 persons) in 1995. There were 22,552 homicides (15% of all injury deaths, for a rate of 8.6 per 100,000) and 31,284 suicides (21% of injury fatalities, for a rate of 11.9 per 100,000) (Bonnie et al., 1999).

For at least 30 years, motor vehicle and firearm injuries have been the two leading causes of injury-related deaths (Bonnie et al., 1999). In 1995, motor vehicle traffic-related injuries accounted for 29% of all injury deaths, or 42,452 deaths. Firearm injuries accounted for 24% of all injury deaths and claimed a total of 35,957 lives. Poisonings were the third leading cause of injury death (11%), followed by falls and suffocation (8% and 7%, respectively); drowning, fires and burns, and cutting and piercing injuries accounted for another 9% of all injury deaths (Fingerhut and Warner, 1997).

Age-adjusted motor vehicle traffic-related death rates declined 15% from 1985 to 1993, but increased 2% from 1993 to 1995. In 1995, 18,428 persons aged 15 to 34 years died of a motor vehicle traffic injury, comprising 43% of all motor vehicle traffic injury deaths. The death rates in this age group declined about 18% from 1985 to 1993, to about 24 per 100,000 individuals (Fingerhut and Warner, 1997). From 1985 to 1995, the alcohol-related fatality rates for those 15-34 years of age declined 32%, and the nonalcohol fatality rates increased 13% (Bonnie et al., 1999).

Occupational injuries resulted in 77,675 fatalities for civilian workers from 1980 to 1992 in the United States. This represents an annual average of 5.5 per 100,000 workers. It has been estimated that in 1995, occupational injuries cost $119 billion in lost wages and productivity, administrative expenses, health care, and other costs (NSC, 1997).

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2.2.2 Overall burden of injury: morbidity

Current surveillance systems collect information about the numbers and types of fatal injuries. However, much less is known about incidence and patterns of nonfatal injuries (Bonnie et al.,1999). It is estimated that almost one in four people in the United States sustains an injury during a single year (Bonnie et al., 1999). In 1995 alone, injuries accounted for an estimated 8% of all short-stay hospital discharges and 37% of all emergency department visits (Bonnie et al., 1999). As for agents of injury, falls are the leading cause of nonfatal injury visits to emergency departments, accounting for approximately 8 million visits to emergency departments yearly. Motor vehicles was the second most important cause of nonfatal injury accounting for approximately 3.8 million visits to hospitals per year (Fingerhut and Warner, 1997).

Although information about nonfatal occupational injuries is not as comprehensive as that for deaths, they are estimated to number more than 13 million each year (Leigh et al., 1997). Nearly one-half (46%) of these injuries are disabling (Bonnie et al., 1999). Approximately one-third of nonfatal injuries occurred among workers in eight industries (restaurants and bars, hospitals, nursing and personal care facilities, trucking and non-air transportation services, grocery stores, department stores, motor vehicles and equipment, and hotels and motels), with the highest incidence rate (17.8 per 100,000 full-time workers) among persons employed in nursing and personal care facilities (BLS, 1997).

Most general nonfatal injuries were of minor severity and did not result in more than one or two days of restricted activities. A large number of injuries resulted in fractures,

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brain damage, major burns, or other significant disability (Bonnie et al., 1999). Fractures typically required six to seven days of hospitalization, where other types of injuries, on average, required three to four days of hospitalization (Fingerhut and Warner, 1997).

2.2.3 The cost of injury

Although the scope of the injuries is measured primarily using numbers or rates of death and years of potential life lost (YPLL) due to premature death, it has become increasingly apparent over the past decade that these methods do not adequately measure the full burden of injuries on society (Bonnie et al., 1999). Totaling deaths and years of life lost does not account for the additional cost to federal, state, and local governments, the cost to private insurance programs, and the costs accruing to injured individuals, their families, employers, and society in general.

In order to make estimates of injury economic cost readily understandable, those estimates usually combine information on incidence and impact of both fatal and nonfatal injuries into a single measure. The costs often include (Bonnie et al., 1999):

(1) Direct costs of medical care (both acute and long term) and other nonmedical goods and services related to injury

(2) Indirect morbidity costs (i.e., the value of foregone productivity due to injury-related illness and disability)

(3) Indirect mortality costs (i.e., the value of foregone productivity due to death at an early age)

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Some analyses also included costs associated with property damage, police and fire services, and legal fees related to compensation (Miller et al., 1995; Blincoe, 1997).

Using a cost-of-illness or human capital approach to value health, estimates of the cost have been derived for several major categories of injury such as motor vehicles, firearms, falls, fires and burns, poisonings (Rice et al., 1989; Max and Rice, 1993; Miller et al., 1995; Blincoe, 1997; Leigh et al., 1997).

One study which evaluated injury cost comprehensively was done by Rice and colleagues (1989). In that study, estimates of the injury cost were derived by age, gender, and six major injury categories (motor vehicle, firearms, falls, fire or burns, poisonings, and drowning or near drowning). Total lifetime costs associated with both fatal and nonfatal injuries were estimated at $158 billion in 1985 and $182 billion in 1988. When inflated to 1995 dollars, the total cost approached $260 billion. The cost of fatalities represented a disproportionate share of total lifetime costs. While accounting for less than 1% of all injuries, fatal injuries contributed to 31% of the total estimated cost. An additional 51% of the cost accrued among persons with injuries resulting in hospitalization. Less than one-fifth of the total costs were associated with overwhelming number of injuries that resulted in one or more days of restricted activity but did not require hospitalization (Rice et al., 1989).

Studies conducted by Miller and colleagues (1994) found that treatment of injuries and their long-term effects (excluding nursing home care and medical care for institutionalized population) accounted for 12% of the total medical care spending in the United States, totaling an estimated $69 billion (in 1993 dollars). Injuries were identified

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as second only to cardiovascular diseases ($80 billion) as a leading contributor to total health care costs. Those authors further estimated that injuries accounted for 10% of all hospital inpatient expenditures, 46% of emergency department expenditures, and 16% of total outpatient and ambulatory care expenditures.

2.3 Patterns of Injury in The General Population

2.3.1 Patterns of injury by demographic characteristics

Social and demographic characteristics may influence risk of injury (Bonnie et al., 1999). Analyzing cause-specific injury data by age, gender, ethnicity or occupation helps to focus prevention planning. Most of the time, surveillance systems can provide information that allows identification of patterns of injury in specific settings. Data from surveillance systems may be used to implement prevention strategies in areas designated at high risk for specific types of injuries or hazards.

Fatal injury

According to a recent report made by the Institute of Medicine (Bonnie et al., 1999), although injury is a leading cause of childhood death, injury death rates are lowest for children under 15 years of age. In 1995, the injury death rate for infants (29 per 100,000 population) was about 2-3 times the rate for children 1-4 years, 5-9 years, and 10-14 years

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of age. For persons age 15-64 years, injury death rates ranged from 49 per 100,000 at 55-64 years to 80 per 100,000 at 20-24 years.

Among older people, although injury is not a leading cause of death (NCIPC, 1998), rates were higher for persons age 75-84 years and 85 years and over at 116 and 281 per 100,000 persons, respectively.

The percentage of all deaths that were caused by an injury was greater for males than for females. Among males age 15-19 years and 20-24 years, 83% and 80%, respectively, of all deaths were caused by injuries compared with 69% and 56% among females. However, with increasing age, the percentages decreased for both males and females (Bonnie et al., 1999). In 1995, for children 1-9 years of age, injury death rates for males were about 1.5 times the rates for females, and the difference increased with age. The mortality sex ratio (the ratio of death rate for males to that for females) jumped from 2.1:1 at age of 10-14 years to 4.6:1 at 20-24 years. The mortality sex ratio for persons age 65 years and over was about 2:1.

Race and ethnicity are a significant factors in injury death rates. The average annual injury death rate for 1993-1995 among teenagers and young adults age 15-34 years was higher for African Americans and American Indian/Alaskan Natives (119 per 100,000) than for Hispanics (78 per 100,000), non-Hispanic white population (58 per 100,000). Unintentional injury death rates and suicide rates were higher for American Indians than for other racial and ethnic groups. Homicide rates were higher for African Americans than for other groups. Motor vehicle traffic injuries were leading causes of unintentional injury in each race and ethnic group (Bonnie et al., 1999).

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Nonfatal Injury

Age and gender patterns for nonfatal injuries are different than those for fatal injuries. Differences by gender among hospital discharge rates for injury were greater for persons aged 15-24 years (31% among males compared with 4% among females) and for persons aged 25-44 years (17% for males compared with 5% for females) than for other ages (Fingerhut and Warner, 1997). For both white and black males aged 15-44 years, 20% of all hospital discharges were for an injury compared with about 5% among females.

In general, discharge rates for persons with a first-listed diagnosis for injury increased with age. In 1993-1994, the average annual rates for children under 5 years of age and 5-14 years of age were 57% and 42% of the rate for young persons aged 15-24 years (90 discharges per 10,000 persons), and that rate was about one-half the rate for persons aged 65-74 years, and about one fifth of the rate for persons aged 75 years and over (412 per 10,000 persons).

Differences by gender were greater for persons aged 15-24 years (31% among males compared with 4% among females) and for persons aged 25-44 years (17% for males compared with 5% for females) than for other ages. For both white and African American males aged 15-44 years, 20% of all hospital discharges were for an injury compared with about 5% among females (NCHS, 1997).

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2.3.2 Patterns of injury by cause

According to National Center for Health Statistics (NCHS, 1997), among children 1-14 years of age, motor vehicle traffic injuries were the leading cause of death in 1995, accounting for an average of 18% of all deaths and 37% of all injury deaths among these children. Among infants, suffocation was the leading cause of injury death. The five leading causes of injury deaths among infants and children under 15 years of age were motor vehicle traffic injuries, fires and burns, drowning, suffocation, and firearms, accounting for 80% of injury deaths. Among teenagers aged 15-19 years and young adults aged 20-24 years, motor vehicles and firearms were the two leading causes of death in 1995. For older adults aged 65-74 years, motor vehicles and firearms accounted for one-half of injury mortality. At ages 75-84 years, motor vehicles and falls were the cause of about one-half of all injury deaths. For those age 85 years and over, falls caused one-third of injury deaths.

Hospital discharge rates for open wounds and for internal injuries for males were 3 times the rate for females. At ages 15-24 years the discharge rate for open wounds for males was 4.5 times the rate for females. On the other hand, discharge rate for poisoning for females aged 15-24 years and 45-64 years were 1.6 times the rate for males. In 1992-1994, three out of five injury hospitalizations among elderly persons aged 75 years and over were fractures. Hip fracture rates for elderly females were twice the rates for males (Bonnie et al., 1999).

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2.3.3 Patterns of occupational injury

The work place is one common environment for injuries. In 1995, 6,210 fatal work injuries (5 per 100,000 workers) were reported in the Census of Fatal Occupational Injuries (BLS, 1997). Overall, transportation-related incidents were the leading cause (23%) of occupational injury deaths. Since 1980, homicide has been the second leading cause of occupational injury deaths, surpassing machine-related deaths (CDC, 1998). About one in six occupational deaths in 1995 was a homicide, which was the leading cause of death for females in occupational settings, accounting for 46% of fatal work injuries (Fingerhut and Warner, 1997). Occupations with the highest risk of fatal injury include truck drivers, fisherman, timber cutters, and airplane pilots.

Information about nonfatal occupational injuries is not as comprehensive as that for deaths. There are estimated more than 13 million nonfatal occupational injuries each year in the United States (Leight et al., 1997). Nearly one-half (46 %) of these injuries are disabling (Leight et al., 1997). Approximately one-third of nonfatal injuries are sustained by workers in eight industries (restaurant and bars, hospitals, nursing and personal care facilities, trucking and non-air courier services, grocery stores, department stores, motor vehicles and equipment, and hotels and motels), with the highest incidence rate reported among persons employed in nursing and personal care facilities (BLS, 1997).

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2.4 Agriculture and Agricultural Injury

2.4.1 Special characteristics of farming population

Agriculture consistently was ranked as one of the most hazardous industries in the United States. Among the most significant and striking occupational hazards seen in agriculture are acute traumatic injuries and deaths. In 1995 alone, workers in the agricultural sector (agriculture, forestry, and fishing) experienced 22 deaths per 100,000 workers, which far exceeded the average annual fatality rate for the U.S. civilian working population for the same time period, 5 deaths per 100,000 workers (BLS, 1995). Every day, about 500 agricultural workers suffer disabling injuries, and almost half of these result in permanent impairment (NIOSH, 1997).

Agriculture has lagged behind other dangerous industries in reducing work-related deaths and injuries (Aherin, 1992). The farming population is unique in a variety of ways. Characteristics of the farming population and the agricultural industry introduce a wide-range of complications in the effort to reduce safety hazards that result in death and injury.

According to the Bureau of Census and U.S. Department of Agriculture (1987), over five and one quarter million people, translating into just over 2% of the U.S. population, claimed farm residence in 1986. Overall, 43.6% of land in the U.S. is devoted to raising food and fiber. The average American farm covers 440 acres. However, the range of farm size is vast. For example, the average farm size in New Jersey is 11 acres, while the

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average size of a Wyoming farm is 3,781 acres (Aherin, 1992).

The small number of U.S. citizens involved directly in farming makes focusing national attention on agricultural related injuries difficult. The dispersion and accompanying seclusion of individual farmers makes safety consultation, educational programs, and enforcement of safety legislation difficult.

Special characteristics of farm work and the farming population put farmers at a high risk of injuries. A greater percentage of farm residents than non-farm residents claimed they were self-employed or unpaid family workers (Aherin, 1992). In 1985, the median income ($21,853) for farm families in the US was 22% less than the median income ($27,881) for non-farm families (Bureau of the Census, 1987). Financial pressure forces farmers to hold multiple jobs. Slightly less than half of all farm operators claimed that their primary occupation was farming (U.S. Bureau of the Census, 1987). Workers with multiple jobs are less likely to have the time and inclination to perform farm work safely, or to use new and safer machinery and equipment on their farms. Therefore, farmers who hold multiple jobs are at higher risk of injuries than full time farm workers (Napier et al., 1985; Xiang et al., 1999). Coughenour and Swanson (1983) found that off-farm employment does effect the labor and capital process of farm business. Off-farm employment of women increases income of the farm, but does not quite compensate for the loss of women's input in farm work.

Off-farm employment could affect safety of farm workers. Research conducted among Colorado farmers (Stallones et al., 1997; Xiang et al., 1998, 1999) reported that male farmers who worked 50 - 199 days per year in off-farm employment had a

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significantly higher rate of injury (30%) than those who did not work in off-farm employment (11%).

One of the farmer's most valuable resource is his or her time. Many farming tasks must be performed in a small window of time for the most productive crops and herds. Farmers often face pressures. In farming, fear in the form of anxiety and worry, arises from unstable markets, competition and day-to-day economic concerns. Farming is intertwined with uncertain events and elements, such as the weather, outbreaks of disease, and volatile markets. In addition, major life changes contribute to stress (Aherin et al., 1992).

Reactions to stress vary considerably among individuals. Some are affected physiologically by psychosomatic illness such as tension and insomnia. Others withdraw by worrying, daydreaming, apathy and sleepiness. All of these reactions to stress can cause decreases in attention, reaction time, and accuracy and judgement in decision-making, leading to injury events (Staeffy et al., 1986).

2.4.2 Risk factors for agricultural injuries

Farmers in the agricultural industry in the United States have received a great deal of attention recently because of their high risk of fatal injuries and suspected risk for serious nonfatal injuries (NIOSH, 1997). Studies have been done to identify specific risk factors that are critical to the development of intervention strategies for the prevention and control of agricultural injuries (BLS, 1997). Risk factors associated with nonfatal farm

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injuries have been categorized into two levels: (1) characteristics of farm environment, and (2) characteristics of farmers.

Studies examining farm environment factors have reported that larger farms, farms with more workers, and farms with higher annual production were associated with a higher injury risks (Zhou et al., 1994; Pickett et al., 1995; Browning et al., 1998; Lewis et al., 1998). Studies have demonstrated that nonfatal injury risk was more significant on farms with animals, especially on beef and dairy farms (Pratt et al., 1992; Brison et al., 1992; Stallones et al., 1993; Nordstrom et al., 1995). The patterns of injury have been fairly consistently reported across these studies, with animal-related injuries, farm machinery, and intentional falls being the three major external causes of injury (Brison et al., 1992; Stallones et al., 1993; Nordstrom et al., 1995). The region of the nation with the highest number of lost-time injuries and highest estimated injury rate was the Midwest (NIOSH, 1997).

With respect to individual risk factors, potential underlying individual characteristics associated with injuries among farm populations have been less well described (Stallones et al.,1997). Greater number of hours spent on farming, full-time farm work, greater cumulative years of farm work experience, and male gender have shown positive associations with higher injury rates (NIOSH, 1992; Brison et al., 1992; Stallones et al., 1993; Nordstrom et al., 1995). Farm operators and their family workers accounted for more injuries, more restricted workdays and a higher injury rate than hired workers, and the race of the worker was typically white (NIOSH, 1997). The relationship between age and agricultural injuries is not well understood. Whether older ages or younger ages are

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associated with higher risk of injury is not clear (Stallones et al., 1997). Although other personal risk factors for injuries, including alcohol consumption, prior traumatic injury, lower levels of education and training, use of prescription medicines, and off-farm employment have been investigated, the evidence for associating these risk factors with farm injuries remains less conclusive (NIOSH, 1992; Stallones et al., 1997; Browning et al., 1998; Xiang et al., 1999).

2.5 Prediction Methods and Injury Prediction

The burgeoning scientific efforts poured into injury control research are based on the assumptions that injuries are health problems and that such events as a group are substantially nonrandom. More and more people have accepted the idea that while no single injury event - just as no single heart attack - can be predicted with complete accuracy, its likelihood can be foreseen to a substantial degree and even quantitatively predicted for specific populations and circumstances. The underlying goals of most aforementioned studies were to identify the high risk population and find the root causes of injuries in order to design intervention or prevention programs to control agricultural injuries (NIOSH, 1992). A majority of these studies used descriptive and analytic approaches to study individual risk factors for injuries and identified high risk individuals by certain characteristics. Unfortunately, little has been done to combine information contained in multiple potential risk factors in a simple way to best assess farmers' risk of injury.

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To control agricultural injuries, it is essential to identify not only various characteristics associated with high risk of injuries, but also, it is important to have an approach to combine all of the information obtained from those multiple characteristics in a single way to best assess injury risks. Prediction of injury events can give individual farmers, physicians, public health nurses, social workers, health educators, legislators, and many others a simple perception of how dangerous certain circumstances could be. Prevention of injuries requires successful convergence of efforts made by all involved (NIOSH, 1992; Petribou, 1995).

Techniques and strategies to determine the best model to predict an outcome in a large data set with a large number of potential predictive variables has become an increasingly important topic in the last decade (Marshall et al., 1994; Zhao et al., 1995; Bailer et al., 1997; Breslow et al., 1997). Predictive models have gained popularity among physicians and public health professionals as an important tool in clinical and public health decision making but few studies have reviewed and assessed reliability of those methods (Leclerc et al., 1988; Phillips et al., 1990; Marshall et al., 1994). Eight methodological strategies for creating predictive models (stepwise logistic regression analysis; logistic regression using all candidate variables; data reduction by cluster analysis and clinical judgement followed by stepwise logistic regression; data reduction by principal components analysis followed by a logistic regression model; a subjectively created 'sickness score' model; a model based on Bayes' theorem; an additive model based on unadjusted relative risk; and a classification tree model) have been compared recently in a large data base to assess the predictive accuracy for the prediction of

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operative death following cardiac surgery (Marshall et al., 1994). The results indicated that the two strategies with the best predictive power among the eight examined models were stepwise logistic regression alone and data reduction by cluster analysis combined with clinical judgement followed by a logistic regression model. In practice, after multivariate data analysis, simple and easy to use integer-based scoring systems have usually been widely created. A composite risk score system was the one used most in epidemiologic studies (Coste et al., 1997).

2.6 Composite Risk Score System and Its Application in Injury Prediction

Composite risk score systems have been increasingly developed for use in epidemiology to combine information contained in a number of risk factors in a way to best evaluate one individual's risk of disease (Coste et al., 1997). Despite controversies regarding the accuracy and generalizability of these systems, they are widely used both by clinicians for predicting the development of disease in individuals free of disease and by public health professionals for evaluating risk in populations or the efficiency of prevention programs (Gail et al., 1989; Chambless et al., 1990; Tu et al., 1994; Harrell, 1996; Coste et al., 1996, 1997). In various domains such as coronary heart disease (Chambless et al., 1990), breast cancer (Gail et al., 1989), burn (Coste et al., 1996), and ectopic pregnancy (Coste et al., 1997), composite risk score systems have been created to quantify risk of morbidity or mortality. In creating a composite risk score system, some descriptive analyses were used as preliminary steps, followed by a logistic modeling

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approach. The descriptive analyses were usually used to provide a general view of the relationships between variables (Coste et al., 1997). It also helped to choose variables for inclusion in final logistic models. After final logistic models were fitted, regression coefficients of the final models were scaled and rounded to integers to make the risk score systems simple to use (Harrell, 1996; Coste et al., 1997). The algorithm proposed by Cole (1993) was usually used to find optimal scaled and rounded coefficients. Coste et al. (1996) showed that the resulting scaled integer coefficients provided predictive ability similar to that provided by the original coefficients. The advantage of the scaled coefficients system is that the final risk scale worksheet is easy to use (Coste et al., 1997).

A composite scale system can be used in two ways (Coste et al., 1997). The first application is to use the computed constant (and appropriate scaling and logistic transformation), as an estimate of absolute risk of a disease or an outcome. The worksheet created by Coste et al. (1997) in an estimation of the absolute risk of ectopic pregnancy in the Auvergne region of France and in populations with similar baseline ectopic pregnancy rates is presented in Figure 2.1 as an example. The second application is to use composite scale as an indicator of the relative risk of a disease or an outcome in a wider context. The relative risk (RR) for disease or outcomes for a given subject is computed simply (Coste et al., 1997):

$$RR = \text{exponential}\ [\text{subject's computed score} \times (\text{scaling coefficient})^{-1}]$$

A unique opportunity exists in Colorado to apply these strategies to design a composite risk score system for estimating nonfatal agricultural injuries among farmers and evaluating this system's predictability using data collected by the Colorado Farm

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Family Health and Hazard Surveillance project (Stallones et al., 1997; Xiang et al., 1998, 1999).

2.7 Possible Contributions to the Field

Agricultural injuries are a major public health concern with devastating and cascading consequences both for the individuals and society. Composite risk score systems, which have been developed for use in epidemiology to combine information contained in a number of risk factors in a way to best evaluate one individual's risk of disease, may provide an useful approach to estimate nonfatal agricultural injury risks among farmers. Using data collected by the Colorado Farm Family Health and Hazard Surveillance project (CFFHHS) between 1993 and 1996, the proposed composite injury risk score system was designed to provide a simple tool to both injury control programs and individual farmers in assessing potential agricultural injury risks among the farming population.

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Ectopic pregnancy (absolute) risk prediction worksheet (to be used in the Auvergne Region, France)

1: Score each risk factor (number of points)

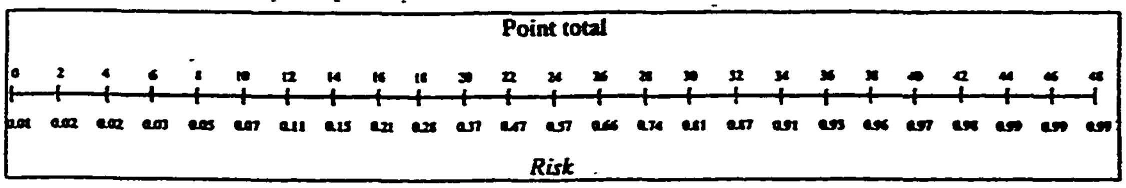
Age(yr)	Points*	Smoking (cig/day)	Points	Other factors	Points Yes	Points No
<35	0	no	0			
35-39	3	≤20	2	Prior ectopic pregnancy	10	0
≥40	6	>20	4	Endometriosis	9	0
				Previous infection	8	0
				Clomiphene-induction	7	0
				Tubal surgery	4	0

2: Add points for all risk factors

___ + ___ + ___ + ___ + ___ + ___ + ___ = ___

Age Smoking Prior ectopic pregnancy Endometriosis Previous infection Clomiphene induction Tubal surgery

3: Read the risk for ectopic pregnancy corresponding to the points total from the following monograph:



(For example, a 36-year old women smoking 25 cigarettes/day, with a previous ectopic pregnancy, and a clomiphene-induced pregnancy will have a score = 3 + 4 + 10 + 7 = 24, which correspond to a risk for ectopic pregnancy = 0.57)

* Points are scaled (×5) coefficients of the logistic model, therefore exp [points × (scaling coefficient)$^{-1}$] represents the odds ratio associated to a given risk factor scheme

Figure 2.1 The procedure to calculate risk probability of ectopic pregnancy using composite score system.

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CHAPTER III

HYPOTHESIS AND STUDY OBJECTIVES

3.1 Hypothesis

The principal hypothesis to be tested in this report is that, contrary to general perceptions, agricultural work-related injuries among farmers are *nonrandom*. The likelihood of agricultural work-related injury can be foreseen and even *quantitatively* predicted, to a substantial degree, for specific populations and circumstances.

3.2. Study Purposes and Scope

The purpose of the proposed study is to evaluate the feasibility and predictability of a composite injury risk score system in the estimation of the probability of agricultural injuries among farmers. The proposed composite injury risk score system will be developed first using statewide survey data collected by CFFHHS among 872 farmers in 1993. Then, the predictability of this injury risk score system will be evaluated both among those statewide farmers who were followed up in 1994 and 1995, and among 761 farmers who were interviewed in eight northen Colorado counties between 1993 and 1996.

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3.3 Specific Objectives

The specific objectives of this dissertation research were to:

1. Identify potential risk factors associated with nonfatal agricultural injuries among Colorado farmers who were interviewed by the Colorado Farm Family Health and Hazard Surveillance project.
2. Model associations between those potential risk factors and nonfatal agricultural injuries using multivariate logistic regression models.
3. Develop an injury risk score system to assess injury risk among individual farmers.
4. Evaluate the predictability of this composite injury risk score system both among those statewide farmers who were followed up in 1994 and 1995 and among 761 farmers who were interviewed in eight northen Colorado counties.

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CHAPTER IV

METHODOLOGY

4.1 Study Design and Study Population: Colorado Farm Family Health and Hazard Surveillance Project

From January 1993 to December 1996, the Colorado Farm Family Health and Hazard Surveillance project (funded by NIOSH) conducted surveys among Colorado farmers. This project collected data in two separate major surveys: a statewide survey and a survey in an eight county northeastern area (Figure 4.1).

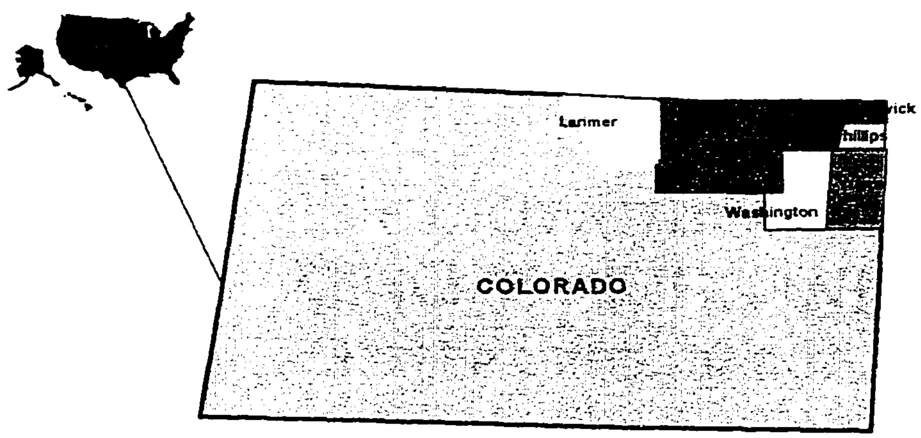

Figure 4.1 Study area of the Colorado Farm Family Health and Hazard Surveillance Project, 1993-1996

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4.1.1 Statewide survey

In this study, a stratified probability sample of farms was selected to represent approximately 2.55% of all rural farm residences with an operator living on the premises in Colorado. The sample was drawn proportional to the number of farms with resident operators in each of the six crop reporting districts identified by Colorado Agricultural Statistics Services (Colorado Agricultural Statistics Service 1990) after excluding the eight county area. Farmers were identified by the Colorado Department of Motor Vehicle Registration list of farm trucks registered in the state of Colorado in 1991-1992. The farm had to make a minimum of $1,000 in a normal year from sales of agricultural products in order to be eligible.

The survey was conducted by telephone and designed to take approximately twenty minutes for each participant. The primary operator and spouse of the operator were asked to participate in the survey. Telephone interviews were conducted separately for the operator and the spouse when both agreed to be interviewed. Detailed questionnaires were administered assessing demographic characteristics, self-perceived health, pre-existing diseases, farm characteristics, pesticides used on the farm in the previous twelve months, injuries, behavioral risk factors, safety knowledge, mental health status, and social support.

At the end of the telephone survey, participants were asked to participate in a follow-up survey during the next two years. For those who agreed to participate, a telephone survey was done using a similar questionnaire. The number of farms participated, and

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number of farmers interviewed each year are listed in Table 4.1.

Table 4.1 Sample Size of Colorado Farm Family Health and Hazard Surveillance Project.

Survey	Year	# of farms participated	# of farmers interviewed	Male	Female
Statewide	1993	485	872	470	402
	1994	396	746	385	361
	1995	331	625	309	316
Eight County Survey	1993-1996	478	761	478	283

4.1.2 Survey in the eight county area

In this survey, a stratified probability sample of 478 farms in eight northeastern Colorado counties (Sedgewick, Phillips, Yuma, Logan, Washington, Morgan, Weld, and Larimer) was selected in proportion to the number of farms in study areas reported in the National Agricultural Statistical Reporting Districts for Crop and Livestock Reporting. Farms were chosen from randomly selected township/range units within each of the eight counties on the basis of the proportion of agricultural land use, the average acreage of the farms, and the probability that the principal operator was a resident on the selected farm. Each residence within the township/range unit was identified using rural directory maps or county property tax assessor's records. The determination of whether or not the dwelling was a farm was based upon the definition used by the Census of Agriculture as a place that sells $1,000 or more in agricultural products in an average year. If the dwelling was eligible for the study, the principal farmers and their spouses residing on the farm

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were asked to participate in the survey. The four-year survey was initiated in January 1993, and data collection was completed in December 1996.

A total of 478 farms were enrolled in the study, representing 761 individual farmers (478 males and 283 females). The survey was conducted by face to face interviews. Detailed information was collected on: farm characteristics, farm chemical use, demographic characteristics, detailed work history, general health questions and social support, hearing loss, work-related injuries, respiratory conditions and allergy, mental health and negative life events, behavioral risk factors, safety knowledge and practices, musculoskeletal conditions, health insurance and medical care, and hazard conditions on farms.

In addition, on-site walk-through safety and hazard appraisals were conducted using industrial hygiene inspections on 134 farms, which were those where the principal operator agreed to a revisit. However, those data will not be analyzed in the current report.

4.1.3 Preliminary findings reported in previous publications

Preliminary analyses indicated that agricultural injury rates among the interviewed farmers ranged from 7.4% to 11.5% (Table 4.2). The injury rate in the second year of the statewide survey was the lowest rate reported.

Several publications (Stallones et al., 1997; Xiang et al., 1998,1999) generated by CFFHHS studied potential risk factors for agricultural injuries among the interviewed

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farmers. The evaluated potential risk factors covered a variety of characteristics of farmers and their agricultural activities.

Table 4.2 Percentage of Work-related Injuries among Colorado Farmers, Colorado Farm Family Health and Hazard Surveillance Project, 1993-1996.

Survey	Year	# in sample	# of injuries	Injury rate (%)
Statewide	1993	872	100	11.5
	1994	746	55	7.4
	1995	653	60	9.2
Eight County	1993-1996	761	85	11.2

Factors which were found to be statistically significant risk factors for agricultural work-related injuries included: gender, age, depressive symptoms, years employed in agriculture, primary agricultural activities on the farm, and off-farm paid employment. There were mixed results regarding other factors. Being deeply in debt and use of prescription medicine was significantly related to injury among older farmers aged 60 years or over. Organophosphate and carbamate pesticides use on the farm in the previous 12 months were associated with injury among male and female farmers. However, the association was not statistically significant at 0.05 level. Alcohol use was assessed among older male farmers age 60 years or over and was found to increase risk of injury. Though not statistically significant, poor self-perceived health status was also found to be a risk factor for injury among older farmers.

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Annual sales value of farm products on the farm (a substitute indicator for farm size), having children who work on the farm, preexisting diseases, and marital status were found not to be associated with agricultural injuries in this study.

4.2 Research Method

4.2.1 Study variables

As described previously, all of the enrolled farmers were interviewed using the CFFHHS questionnaire, which was patterned after the one used in the 1988 National Health Interview Survey, Occupational Health Supplement (NHIS/OHS). The final questionnaire was pilot-tested among a small group of Colorado farmers before the formal survey. Detailed questions were included to assess demographic characteristics, self-perceived health, pre-existing diseases, farm characteristics, pesticides used on the farm in the previous twelve months, injuries, behavioral risk factors, safety knowledge, mental health status, negative life events, and social support. For the purposes of the current report, relevant variables have been selected and categorized into the following groups (Appendix III):

(1) Demographic and socio-economic variables: age, gender, marital status, education years, race, ever smoked, current smoking, and years of cigarette smoking.

(2) Farm characteristic variables: size of farm, annual sales value of farm products, primary cash products, pesticides used on farm, and tractor/truck used on farm.

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(3) Work practice and behavioral risk variables: occupation (primary duties on farm), off-farm employment in the past year, worked on someone else's farm or ranch in previous 12 months, years involved in agriculture, and seat belt use.

(4) Negative life events, physical and emotional variables: lost something of sentimental value, close friend died, divorced or separated, had trouble with in-laws, spouse died, family member died, income decreased substantially, gone deeply into debt, had legal problems, been assaulted, were depressed, health status, back pain, arthritis, hearing loss, high blood pressure.

All of the information regarding the above variables were self-reported by farmers. Pre-existing diseases were determined by asking the question "Has a doctor ever told you that you had any of the following diseases?". If the interviewee answered "Yes", then the year when he/she received a physician diagnosis of the condition was asked. The question "Have you gone deeply into debt within the past twelve months ?" was asked to assess the financial situation of the farmers. However, no quantitative description of the debt was asked.

Depression status was determined using the Center for Epidemiologic Studies Depression (CESD) scale, which contains a series of 20 psychosocial questions and has been used in numerous studies (Goldberg et al., 1985; Stallones et al., 1995; Radloff, 1997). The possible score from this scale ranges from 0 to 60. The CESD scale has been shown to be a valid screening tool for detecting depressive symptoms among general population and validated among psychiatric populations. A score of 16 or higher has been used by other investigators (Goldberg et al., 1985; Stallones et al., 1995) to indicate

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depression status and thus was used in this report to indicate depression status among the farmers.

4.2.2 Study outcomes

Individual farmers were asked to report if they had experienced a farm work-related injury in the previous twelve months which had resulted in: seeking medical attention or treatment other than first aid, having been unable to do some work activities or having lost consciousness, or having had to transfer to another job. In this report, an "agricultural injury case" was defined as a farmer who answered "Yes" to the question "During the past 12 months, that is, since (12-month date) a year ago, have you had any farm work-related injuries ?". Details about reported injuries (part of body injured, date of injury, work activities at the time of the injury, how the injury occurred, type of medical attention sought, and amount of work time lost) were obtained.

4.2.3 Statistical analysis

The SAS statistics package (1990) was used to conduct data analysis for this report. The analyses were completed in several stages.

First, characteristics of injuries occurred to those farmers enrolled in CFFHHS by nature of injury (N-code) and external cause of injury (E-code) were described. The N-codes and E-codes were from the 9th Revision of International Statistical Classification of

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Diseases, Injuries and Causes of Death, and were coded by experts associated with the Colorado Department of Public Health and Environment.

Second, analyses were done to describe the characteristics of all enrolled farmers in the first year statewide survey and percentage of injury using the first injury that occurred to those farmers during the whole three year study period with regard to demographic and socio-economic variables, farm characteristics, work practice and behavioral risk factors, and negative life events, physical and emotional status. Mantel-Haenzel Chi-square tests were computed and the associated P-values were reported in order to compare injury rates between groups.

Third, the logistic regression models to estimate odds ratios (OR) along with their associated 95% confidence intervals (95% CI) were constructed. Crude OR and 95% CI for a particular risk factor were calculated by entering only that study variable of interest into the logistic regression model as the independent variable and injury status ("Yes = 1" or "No = 0") as the dependent variable. Then, those variables which were statistically significant risk factors for injury at $P < 0.1$ level were put together into the logistic regression model and a backward elimination modeling strategy was used to select statistically significant risk factors for injury in final multivariate logistic regression models. In the analyses, dummy variables were created for study characteristics if the categories included more than two groups. The referent group was generally the group with the lowest percentage of injuries.

After statistically significant variables were identified, logistic regression models were fitted again to the first year statewide data by using those variables as independent

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variables and injuries that occurred in the first year of the statewide survey as dependent variables. Two-way interaction terms among those variables were evaluated, and variables retained in the final logistic regression models were used in the construction of the composite injury risk score system which will be described below in detail.

4.2.4 Development of composite injury risk score system

1. Developing logistic regression models

Techniques and strategies to determine the best model to predict an outcome in a large data set with a large number of potential predictive variables have become an increasingly important topic in the last decades (Brieman et al., 1984; Edwards et al., 1984, 1988; Parsonnet et al., 1989; Chambless et al., 1990; Philips et al., 1990; Hastie et al., 1990; Friedman, 1991; Marshall et al., 1994; Bailer et al., 1997). Multivariate logistic regression is a popular mathematical modeling approach in epidemiology. The logistic regression modeling assumes that for given levels of a specified set of risk factors, the probability of P for development of an outcome over a fixed period of time is related to risk factors by equation

$$P(y=1|x)=\frac{e^{\alpha+\beta_1x_1+\beta_2x_2+...+\beta_kx_k}}{1+e^{\alpha+\beta_1x_1+\beta_2x_2+...+\beta_kx_k}} \qquad \text{(Equation 1)}$$

Where Y is the dependent variable, α is a constant term, β_i is regression coefficient,

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and the x_i is independent variable. In this model, the dependent variable may be either zero or one. This model was introduced for analysis of injury among farmers in our study where outcome is the injury given a set of risk factors.

If we use the natural logarithm of the odds that Y = 1, the equation for the relationship between dependent the variable and independent variables, then the equation becomes

$$Logit(y) = \alpha + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_p x_p \qquad \text{(Equation 2)}$$

where logit (Y) = ln[P(Y=1|X)/P(Y=0|X)].

This equation is the model used in the final multivariate logistic regression analyses.

2. Scaling and rounding regression coefficients into integers

The logistic regression models (equation 2) can be used to predict the probability that a farmer will be classified into one category (injured, y=1) as opposed to other (not injured, y=0) category of the dependent variable.

However, in many situations, it is the predicted ranking of individuals that counts rather than the absolute value of predictors so that the regression coefficients can be scaled arbitrarily. This is particularly useful if a simple manual scoring system (Cole et al., 1991) can be developed. If the scaling factor is chosen appropriately, the scaled coefficients can be rounded to integers without much loss of precision. Scaled coefficients simplify the injury risk scoring system. Furthermore, if the x_i is chosen to

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be binary (0,1) variable (which was the case in our study), then the scoring system consists of simply adding integer scores together.

For example, we used following equation to scale and round predictors

$$Z(k)_j = \sum [k\beta_i] x_i \qquad \text{(Equation 3)}$$

where k is a scaling factor, and each scaled coefficient $k\beta_i$ is rounded to an integer, denoted by [$k\beta_i$]. Note that $Z(k_i)$ will classify individuals in the same way as y_j apart from a rounding error. So we have

$$y_i = \frac{Z(k)_j}{k} + \varepsilon(k)_j \qquad \text{(Equation 4)}$$

where $\varepsilon(k)_j$ is the rounding error caused by the particular choice of k.

Goodness of fit of $Z(k_j)$ is given by the uncorrected variance of $\varepsilon(k)_j$

$$\sigma^2(k) = \sum \frac{\{y_i - z(k)_j / k\}^2}{N} \qquad (5)$$

In general, as k increases, $\sigma^2(k)$ decreases. However, superimposed on the trend are some cyclical variations, so that certain values of k provide a better fit than others nearby. A Fortran 77 algorithm has been developed by Cole (1993) to identify such locally optimal scaling factors (the Fortran 77 program is attached as Appendix) .

In the current report, regression coefficients from the final multivariate logistic regression models were scaled and rounded into integers using the algorithm developed

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by Cole (1993). Those coefficient integers were used in the next step to develop injury risk scores.

3. Building composite injury risk scores

Regression coefficients in the final multivariate logistic regression model were scaled and rounded into integers. Then, a injury risk score was calculated for each farmer using his or her characteristics related to risk factors in the final logistic regression model. The injury risk score for a particular farmer is

$$\text{Injury risk score} = \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_k x_k \qquad \text{(Equation 6)}$$

Since each independent variable x_i was chosen to be a binary (0,1) variable and all of the logistic regression coefficients β_i were scaled and rounded into integers, the injury risk score was simply calculated as

$$\text{Injury risk score} = \beta_1^* + \beta_2^* + \ldots + \beta_k^* \qquad \text{(Equation 7)}$$

where β_i^* is the scaled regression coefficient integer.

According to equation (2), we have

$$Log_e[\frac{P}{1-p}] = \alpha + \underbrace{\beta_1^* + \beta_2^* + \ldots + \beta_k^*}_{Injury\ \ Risk\ \ Score} \qquad \text{(Equation 8)}$$

where p is the probability of injury for that particular farmer, so that $\log_e(\frac{P}{1-p})$ has a

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linear relationship with the injury risk score .

Using the injury risk scores calculated from relevant variables (characteristics of farmer), the probability of injury over a fixed period of time can be predicted, theoretically, by equation (8).

4. Assessing the predictability of the injury prediction methods

The composite injury risk score system developed in this project, which allows the use of parametric statistics, is characterized by its ability to preserve distances between subjects with respect to the measured phenomenon. It implies that there must be a linear relationship between the composite risk score and the measured injury risks. Therefore, linear regression and the square of the multiple correlation coefficient (R^2) can be used as an indicator of the linear relationship between the composite injury risk scores and the measured injury risks.

Because of the limited number of farmers in our sample, it was very difficult to get a sufficient individuals who had the same value of injury risk scores. To solve this problem, the enrolled farmers were categorized by their injury risk scores into 8 subgroups in the statewide surveys and 6 subgroups in the eight county survey. Then, the actual proportion of injured farmers in each subgroup was calculated by dividing the total number of observed injuries by the total number of farmers in that particular subgroup.

To evaluate predictability of the injury risk scores, medians of composite risk scores in each subgroup were used as the independent variable, and the associated (logit of)

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observed proportions of injured farmers were used as the dependent variable. The median injury risk scores were plotted against observed proportions of injuries to assess the relationship visually. Simple linear regression models were fitted to study the relationship between the median composite injury risk scores and the observed proportion of injuries among the enrolled farmers.

The injury risk prediction model was developed first using first year statewide data collected in 1993. Then, the predictability of this composite injury risk score system was evaluated using data collected in the second and third year follow-up (same population, time frame), and data collected by survey in the eight county (different study population). Statistics of goodness of fit and R^2 for models in validation samples were calculated for assessing predictability of the injury risk score methods.

Finally, an injury risk prediction worksheet, like the one used by Coste and his colleagues (1997), was created using first the year statewide survey data. It can be used in the estimation of agricultural injury risk among Colorado farmers.

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CHAPTER V

RESULTS

5.1 Work-related Injuries among Colorado Farmers

According to several previous publications (Stallones et al., 1997; Xiang et al.,1998, 1999), 872 adults (470 male and 402 female) aged ≥18 years were interviewed in 1993 on 458 farms in the statewide telephone survey. Seven hundred forty six (85.6%) out of 872 participants were followed up in the second year statewide survey, and six hundred twenty five (83.8%) out of the 746 second year participants were followed up in the third year by telephone using same questionnaire (Table 4.1). In the eight county area, a total of 478 farms agreed to participate in a face to face interviewing survey, representing 761 individuals (478 male and 283 female).

The response rate for the first year of the statewide survey, based on subtracting refusals and procedural interview failures (i.e., could not understand the interviewer or the questions), was 62% for the total study population. The response rate based on outright refusal to participate when an eligible household was contacted was 70%. No information was obtained from those who refused to participate.

According to one previous publication (Xiang et al., 1999), of those farms investigated, 4.9% were small farms with a size between 1 and 49 acres, 27.8% had a size between 50 and 499 acres, 35.0% had a size between 500 and 1,999 acres, and

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32.3% had a size over 2,000 acres. The leading cash products on those farms were field crops or cash grains (63.5%) and livestock (30.4%). Regarding agricultural products sales, 46.6% of those farms had more than $100,000 in sales value of all products, 26.1% had a sales value of all products between $40,000 and $99,000, and 27.4% had a sales value of all products below $39,000. Most (86.4%) of the farms employed less than 5 regular workers. All of the interviewed males and a majority of the interviewed females (83%) reported being involved in farming activities in the previous year preceding the survey.

The agricultural injury rates among farmers interviewed ranged from 7.4% to 11.5% during the study period (Table 4.2). The injury rate in the second year statewide survey was the lowest.

The characteristics of the reported injuries among the enrolled farmers are summarized in Table 5.1 and Table 5.2. The leading causes of those injuries were overexertion (21% - 30%), animals (10% - 25%), falls (11% - 23%), and sharp objects (9% - 20%). The injuries mainly resulted in sprains and strains (30% - 38%), fractures (14% - 20%), and open wounds (5% - 20%). Farm machines caused only 6% - 9% of all the agricultural work-related injuries in this study.

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Table 5.1 Number and Percentage of External Causes for Reported Injuries: Colorado Farm Family Health and Hazard Surveillance, 1993-1996.

		Statewide Survey						Eight County Survey	
		First Year		Second Year		Third Year			
E-Code	Description	No.	%	No.	%	No.	%	No.	%
E927	Overexertion	24	24.0	18	32.7	18	30.0	18	21.2
E906	Injury by animals	20	20.0	6	10.9	15	25.0	22	25.9
E880-E888	Falls	18	18.0	13	23.6	7	11.7	10	11.8
E916-E918	Struck against, or by	14	14.0	5	9.1	12	20.0	10	11.8
E919-E920	Tools and other sharp objects	11	11.0	6	10.9	-	-	11	12.9
E919	Farm machines	9	9.0	4	7.3	4	6.7	5	5.9
E860-E869	Poisoning	2	2.0	-	-	-	-	2	2.4
E928	Unspecified	2	2.0	3	5.5	4	6.7	7	8.2
Total		100	100.0	55	100.0	60	100.0	85	100.0

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Table 5.2 Number and Percentage of Nature of Injury for Reported Injuries: Colorado Farm Family Health and Hazard Surveillance, 1993-1996.

		Statewide Survey						Eight County Survey	
		First Year		Second Year		Third Year			
N-Code	Description	No.	%	No.	%	No.	%	No.	%
N840-N848	Sprains and strains	29	29.0	16	29.1	21	35.0	32	37.5
N871-N897	Open wounds	20	20.0	4	5.5	12	20.0	13	15.3
N800-N829	Fractures	14	14.0	12	21.8	9	15.0	17	20.0
N959	Unspecified and other	12	12.0	2	2.4	2	3.3	2	2.4
N915-N924	Superficial injuries and Contusions	9	9.0	9	16.4	8	13.3	4	4.7
N722	Disorder of bone	9	9.0	6	10.9	2	3.3	3	3.5
N830-N839	Dislocation	5	5.0	5	9.1	6	10.0	8	9.4
N930	Foreign body in eye	2	2.0	2	2.4	-	-	6	7.1
Total		100	100.0	55	100.0	60	100.0	85	100.0

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5.2 Risk Factors for Work-related Injuries among Colorado Farmers

Table 5.3 to Table 5.6 summarized the number of first injury occurred among farmers over the three study period of statewide survey, percentage of injury, and the unadjusted ORs with associated 95% CI by demographic and socio-economic variables, work practice and behavioral risk variables, negative life events, and physical and emotional variables.

The results indicated that young farmers aged 30-39 years (OR = 2.11; 95% CI = 1.26 - 3.54) and male farmers (OR = 1.97; 95% CI = 1.36 - 2.86) were significantly more likely to have agricultural work-related injuries. Consistent with findings from other studies, alcohol drinking and cigarette smoking were statistically significant risk factors for work-related injuries among farmers. Those who were classified as heavy and moderate drinkers, based on the self-reported information, had a higher injury risk than those who were classified as nondrinkers or light drinkers (heavy drinkers compared to nondrinkers: OR = 1.78; 95% CI = 1.21 - 2.58; moderate drinkers compared to nondrinkers: OR = 1.84; 95% CI = 0.81 - 4.21). Those who smoked more than 20 cigarettes per day were at a statistically significant elevated risk of injury (OR = 1.79; 95% CI = 1.03 - 3.13). However, marital status, education level, race were not associated with risk of work-related injury in this population.

Those farmers who reported farming or ranching as their main occupation had a significantly higher percentage of injury (22%) compared to other farmers whose main occupation was not farming or ranching (12%). Farmers who worked 50 to 149 days in

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off-farm employment per year (OR = 2.19; 95% CI = 1.42 - 3.35), who worked on someone else's farm in the past year (OR = 1.66; 95% CI = 1.10 - 3.17), and who applied insecticides on livestock in the last year (OR = 1.59; 95% CI = 1.11 - 2.27) were significantly more likely to have agricultural work-related injuries. Farmers who always used seatbelts had a significantly lower percentage of agricultural work-related injury (15%).

Negative life events and emotions were a statistically significant risk factor for agricultural work-related injuries in this population. Those farmers who reported loss something of sentimental value had a significant higher injury rate (29%) than farmers who did not report loss sentimental things (15%). Agricultural work-related injuries were more likely to occur to those farmers who had a family member die (OR = 1.64; 95% CI = 1.13 - 2.39), and who reported a substantial decrease in family income (OR = 1.89; 95% CI = 1.05 - 3.39) or deep debt (OR = 1.30; 95% CI = 0.87 - 1.95). Those who had legal problems (OR = 1.89; 95% CI = 1.05 - 3.39) and those who had depression by the criteria of the Center for Epidemiologic Studies Depression Scale (OR = 1.74; 95% CI = 1.01 - 2.98) also had a significantly higher risk of injuries.

Elevated injury risks were also associated with self-reported poor health. Those who reported back pain (OR = 2.53; 95% CI = 1.56 - 4.09), hearing loss (OR = 1.97; 95% CI =1.22 - 3.19), and high blood pressure (OR = 1.48; 95% CI = 1.01 - 2.19) were at higher risk of injury.

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Table 5.3 Number and Percentage of Agricultural Injuries, Odds Ratio, and 95% Confidence Interval by Selected Demographic Variables: Statewide Survey, Colorado Farm Family Health and Hazard Surveillance, 1993-1995.

Variable	# in Study Sample	# Injured	Percentage Injured (%)	P-value*	OR (95% CI) (Unadjusted)
Age in years					
20-29	59	14	23.7	0.001	1.63(0.78-3.44)
30-39	206	56	27.2		2.11(1.26-3.54)
40-49	238	28	11.8		0.75(0.43-1.34)
50-59	196	26	13.3		0.87(0.48-1.56)
60 +	173	26	15.0		Referent
Gender					
Male	470	101	21.5	0.001	1.97(1.36-2.86)
Female	402	49	12.1		Referent
Maritai status					
Married	810	137	16.9	0.707	0.83(0.43-1.60)
Other	61	12	19.6		Referent
Years in school					
12 or less	396	71	17.9	0.618	1.10(0.76-1.58)
13-15	256	42	16.4		0.89(0.40-1.97)
16 or more	218	36	16.5		Referent
Race					
White	857	146	17.0	0.665	0.75(0.21-2.73)
Other	14	3	21.4		Referent
Ever smoked					
Yes	370	67	18.1	0.467	1.14(0.80-1.63)
No	499	81	16.2		Referent
Current smoker					
Yes	119	27	22.7	0.088	1.50(0.94-2.41)
No	753	123	16.3		Referent

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Table 5.3 (continue) Number and Percentage of Agricultural Injuries, Odds Ratio, and 95% Confidence Interval by Selected Demographic Variables: Statewide Survey, Colorado Farm Family Health and Hazard Surveillance, 1993-1995.

Variable	# in Study Sample	#Injured	Percentage Injured (%)	P-value*	OR (95% CI) (Unadjusted)
Years smoked cigarette					
None	505	83	16.4	0.713	Referent
1 -10	12	4	33.3		2.48(0.73-8.43)
11-20	52	9	17.3		1.04(0.49-2.21)
21+	286	50	17.5		1.05(0.72-1.54)
Average cigarettes smoked per day					
0	753	124	16.5	0.023	Referent
1 - 10	29	3	10.3		0.59(0.18-1.97)
11 - 20	14	4	28.6		2.04(0.63-6.60)
20 +	73	19	26.0		1.79(1.03-3.13)
Level of alcohol drink					
None or light	510	73	14.3	0.002	Referent
Moderate	227	50	22.0		1.84(0.81-4.21)
Heavy	118	27	22.9		1.77(1.21-2.58)

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Table 5.4 Number and Percentage of Agricultural Injuries, Odds Ratio, and 95% Confidence Interval by Selected Farm Characteristics: Statewide Survey, Colorado Farm Family Health and Hazard Surveillance, 1993-1995.

Variable	# in Study Sample	#Injured	Percentage Injured (%)	P-value*	OR (95% CI) (Unadjusted)
Annual sales values of all products					
0 - 39 thousand	390	57	14.6	0.027	Referent
40- 99 thousand	195	38	19.5		1.41(0.90-2.22)
100+ thousand	261	46	17.6		1.25(0.82-1.91)
Primary cash products					
Field & crop	384	63	16.4	0.929	1.02(0.57-1.82)
Livestock (cattle)	342	62	18.1		1.15(0.64-2.06)
Livestock (sheep, hogs, & goats)	34	6	17.7		1.11(0.40-3.09)
Other (forest, nut, Vegetable, fruit)	105	17	16.2		Referent
Herbicides used on farm					
Yes	413	78	18.9	0.196	1.26(0.89-1.80)
No	456	71	15.6		Referent
Crop insecticides used on farm					
Yes	248	52	21.0	0.068	1.42(0.97-2.06)
No	615	97	15.8		Referent
Insecticides used on livestock					
Yes	330	70	21.2	0.011	1.59(1.11-2.27)
No	538	78	14.5		Referent
Acres in use					
≤500	556	97	17.5	0.724	1.07(0.74-1.55)
500 +	315	52	16.5		

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Table 5.5 Number and Percentage of Agricultural Injuries, Odds Ratio, and 95% Confidence Interval by Selected Work Practice and Behavioral Characteristics: Statewide Survey, Colorado Farm Family Health and Hazard Surveillance, 1993-1995.

Variable	# in Study Sample	#Injured	Percentage Injured (%)	P-value*	OR (95% CI) (Unadjusted)
Occupation					
Farming or ranch	430	96	22.3	0.001	2.19(1.43-3.35)
Homemaking	149	19	12.8		1.11(0.61-2.03)
Student	8	1	12.5		1.09(0.13-9.11)
Other	284	33	11.6		Referent
Days worked in off-farm employment in the past year					
0 - 49	492	89	18.1	0.034	Referent
50 - 149	91	27	29.7		1.91(1.15-3.17)
150+	286	33	11.5		0.59(0.38-0.91)
Worked on someone else's farm or ranch					
Yes	152	36	23.7	0.018	1.66(1.09-2.54)
No	719	113	15.7		
Years involved in agricultural work					
0 - 9	112	17	15.2	0.856	0.87(0.49-1.55)
10- 29	360	65	18.1		1.07(0.74-1.56)
30+	389	66	17.0		Referent
Use seat belt when drive or ride a car					
Always	327	49	15.0	0.080	Referent
Sometimes	482	85	17.6		1.22(0.83-1.78)
Never	61	15	24.6		1.85(0.96-3.57)

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Table 5.6 Number Percentage of Agricultural Injuries, Odds Ratio, and 95% Confidence Interval by Selected Negative Life Events, Physical and Emotional Characteristics: Statewide Survey, Colorado Farm Family Health and Hazard Surveillance, 1993-1995.

Variable	# in Study Sample	#Injured	Percentage Injured (%)	P-value*	OR (95% CI) (Unadjusted)
Lost something of sentimental value					
Yes	154	45	29.2	0.001	2.43(1.62-3.64)
No	716	104	14.5		Referent
Close friend died					
Yes	295	57	19.3	0.173	1.26(0.87-1.81)
No	574	92	16.0		Referent
Divorced or separated					
Yes	25	3	12.0	0.639	0.65(0.19-2.21)
No	844	146	17.3		Referent
Trouble with in-laws					
Yes	80	19	23.8	0.187	1.59(0.92-2.75)
No	788	129	16.4		Referent
Spouse died					
Yes	15	2	13.3	0.752	0.74(0.17-3.31)
No	854	147	17.2		Referent
Family member died					
Yes	234	53	22.7	0.027	1.64(1.13-2.39)
No	635	96	15.1		Referent
Income decreased substantially					
Yes	198	40	20.2	0.197	1.89(1.05-3.39)
No	670	109	16.3		Referent

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Table 5.6 (continue) Number and Percentage of Agricultural Injuries, Odds Ratio, and 95% Confidence Interval by Selected Negative Life Events, Physical and Emotional Characteristics: Statewide Survey, Colorado Farm Family Health and Hazard Surveillance, 1993-1995.

Variable	# in Study Sample	#Injured	Percentage Injured (%)	P-value	OR (95% CI) (Unadjusted)
Gone deeply into debt					
Yes	126	29	23.0	0.054	1.30(0.87-1.95)
No	742	119	16.0		Referent
Had legal problems					
Yes	63	17	27.0	0.001	1.89(1.05-3.39)
No	806	132	16.4		Referent
Been assaulted					
Yes	9	0	-	-	-
No	860	149	17.3		
Had depression					
Yes	80	20	25.0	0.044	1.74(1.01-2.98)
No	782	126	16.1		Referent
Self-evaluation of health status					
Excellent	281	32	11.4	0.045	Referent
Very good or good	530	106	20.0		1.95(1.27-2.98)
Fair or poor	60	11	18.3		1.75(0.83-3.70)
Had back pain					
Yes	92	29	31.5	0.001	2.53(1.56-4.09)
No	779	120	15.4		Referent
Had arthritis					
Yes	139	27	19.4	0.429	1.17(0.74-1.84)
No	732	122	16.7		Referent
Had hearing loss					
Yes	100	27	27.0	0.005	1.97(1.22-3.19)
No	771	122	15.8		Referent
High blood pressure					
Yes	700	125	17.9	0.047	1.48(1.01-2.19)
No	171	24	14.0		Referent

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The final multivariate logistic regression model verified the findings from univariate analysis. Age, gender, occupation, primary farm products, paid days in off-farm employment, loss of something of sentimental value, legal problems, alcohol drinking, health status, and back pain status were retained in the final models. Injured farmers were significantly more likely to be males, young farmers, those who reported farming or ranching as the main occupation, farmers involved in animal production, those worked 50-149 days in off-farm employment, farmers who lost something of sentimental value, those who had legal problems, and those with poor self-reported health status (Table 5.7).

Table 5.7 Parameter Estimates (β), Standard Error (SE), Odds Ratio (OR), and Statistics of Fit of the Final Logistic Regression Model.

Variable	β	SE	OR	(95% CI)
Age 20-29	0.808	0.533	2.24	(0.79-6.38)
30-39	0.809	0.398	2.25	(1.03-4.90)
40-49	0.078	0.427	1.08	(0.47-2.49)
50-59	0.460	0.417	1.58	(0.70-3.59)
Male	0.452	0.310	1.57	(0.86-2.89)
Farming or ranching	0.670	0.296	1.96	(1.09-3.50)
Good health	0.632	0.321	1.88	(1.00-3.53)
Bad health	1.096	0.503	2.99	(1.12-8.02)
Back pain	0.927	0.330	2.53	(1.32-4.83)
Loss of sentimental things	0.625	0.290	1.87	(1.06-3.30)
Legal problem	0.853	0.397	2.35	(1.08-5.12)
Moderate alcohol drinker	0.702	0.559	2.02	(0.68-6.03)
Heavy alcohol drinker	0.525	0.272	1.69	(0.99-2.88)
Big livestocks handling	0.354	0.261	1.43	(0.85-2.38)
Small livestocks handling	1.119	0.553	3.06	(1.04-9.05)
Off-farm employment (50-149 days)	0.934	0.333	2.55	(1.33-4.88)
Goodness-of-fit statistics				
-2 log-likelihood	522.37 (P-value < 0.0001)			
C index	0.745			

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Next, all of the two-way interaction terms among those ten variables retained in the final logistic regression models were evaluated. Results indicated that two interaction terms (loss of things of sentimental value* off-farm employment; back pain*livestock as a major farm production) were statistically significant ($P < 0.05$). However, adding these two interaction terms into logistic regression model did not significantly improve predictive efficiency of the model. All of the four indices for assessing predictive ability of logistic regression model (Somers' D, Goodman-Kruskal's Gamma, Kendall's Tau-a, and c) barely changed after the two interaction terms were added. Therefore, the interaction terms were not used in the final model on which the injury risk score was based.

5.3 Logistic Regression Coefficients Scaled into Integers

Based on the results from final logistic regression models, all of the regression coefficients were scaled and rounded into integers using a Fortran 77 algorithm developed by Cole (1993). The results were reported in Table 5.8.

There were two options of scaled coefficient integers for use in the prediction of agricultural work-related injuries among farmers.

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Table 5.8 Results of Scaling and Rounding Coefficient for Variables in Final Prediction Model, Colorado Farm Family Health and Hazard Surveillance, 1993-1996.

Solution	k	SD	kSD	Integer scores
1	6.402	0.0388	0.2482	(5, 5, 1, 3, 3, 4, 7, 4, 6, 4, 6, 5, 3, 2, 7, 6)
2	7.484	0.0359	0.2686	
3	8.409	0.0309	0.2594	
4	8.978	0.0299	0.2686	
5	9.492	0.0273	0.2592	
6	10.917	0.0182	0.1982	(9, 9, 1, 5, 5, 7, 12, 7, 10, 7, 9, 8, 6, 4, 12, 10)
7	13.819	0.0175	0.2418	
8	14.889	0.0166	0.2464	

Corresponding variables included in the final prediction model:
(age1, age2, age3, age4, gender, health2, health3, occupat1, backpain, lost96a. legal96i,alcohol2, alchohol3, cashcrp2, cashcrp3, paidemp2)

Using procedures described in detail in Table 5.12, the agricultural work-related injury risk score was calculated for each farmer who was interviewed in the statewide survey and the eight county survey. Then farmers were grouped into several subgroups by their calculated injury risk scores.

5.4 Composite Injury Risk Scores and Observed Proportions of Injury

Table 5.9 and Table 5.10 reported the composite injury risk scores and the observed proportions of agricultural work-related injuries among farmers interviewed by the Colorado Farm Family Health and Hazard Surveillance project. The results indicated that the higher the composite injury risk scores, the higher the observed proportions of work-related injuries among those farmers.

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Table 5.9 Composite Risk Scores and Observed Proportion of Injury in Statewide Survey: Colorado Farm Family Health and Hazard Surveillance, 1993-1995.

Risk Score		Observed Number and Percentage of Injury					
		Year 1		Year 2		Year3	
Range	Median	n/N	%(p)	n/N	%(p)	n/N	%(p)
0 - 7	5	0/44	-	1/42	0.02381	1/32	0.03226
8 - 13	12	3/119	0.02521	6/107	0.05608	7/94	0.07447
14-19	17	4/166	0.02410	4/150	0.02667	8/128	0.06250
20-25	23	16/173	0.09249	5/140	0.03571	8/119	0.06723
26-31	28	12/171	0.07018	12/148	0.08108	8/120	0.06667
32-37	34	24/96	0.25000	17/78	0.21795	11/66	0.16667
38-43	39	16/53	0.30189	6/43	0.13954	6/34	0.17647
44-59	48	20/34	0.58824	3/28	0.10714	9/27	0.33333

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Table 5.10 Composite Risk Scores and Observed Proportion of Injury in Eight County Survey: Colorado Farm Family Health and Hazard Surveillance, 1993-1996.

Risk Score		Observed Number and Percentage of Injury	
Range	Median	n/N	%(p)
0 - 8	6	3/55	0.05455
9 - 15	13	6/112	0.05357
16-22	20	20/172	0.11628
23-29	25	22/223	0.09866
30-36	33	18/109	0.16514
37-54	40	13/54	0.24074

The Pearson correlation analysis (Table 5.11) indicated high correlations between the calculated composite injury risk scores and $\log_e(\frac{P}{1-P})$. The lowest correlation coefficient (0.784) was found among farmers interviewed in the second year of the statewide survey. The correlation coefficient for farmers interviewed in the third year of the statewide survey was 0.932.

Based on information provided by the final logistic regression models, composite injury risk scores were calculated for farmers in the eight county survey, and the correlation between composite injury risk scores and observed proportion of injuries among those farmers was also found to be highly significant ($r = 0.959$, Table 5.11).

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Table 5.11 Pearson Correlation Coefficients between Logit of Observed Proportion of Injury among Farmers and Composite Risk Scores.

Variables	Risk Score	Pearson Correlation Coefficient
Ln(P1/Q1)	Score	0.975
Ln(P2/Q2)	Score	0.784
Ln(P3/Q3)	Score	0.932
Ln(P8/Q8)	Score	0.959

5.5 Evaluation of Composite Injury Risk Scores

According to equation (8) described in Chapter IV, $\log_e(\frac{P}{1-P})$ should have a linear relationship with injury risk scores. The $\log_e(\frac{P}{1-P})$ for farmers in each subgroup was calculated using the observed proportions of work-related injuries and then the relationships between the median of the composite injury risk scores and the $\log_e(\frac{P}{1-P})$ were evaluated.

Figure 5.1 - Figure 5.4 showed us the relationship between those two variables visually. In particular, the straightline linear relationship between $\log_e(\frac{P}{1-P})$ and the composite injury risk scores was indicated for farmers in the statewide survey as well as for farmers in the eight county survey.

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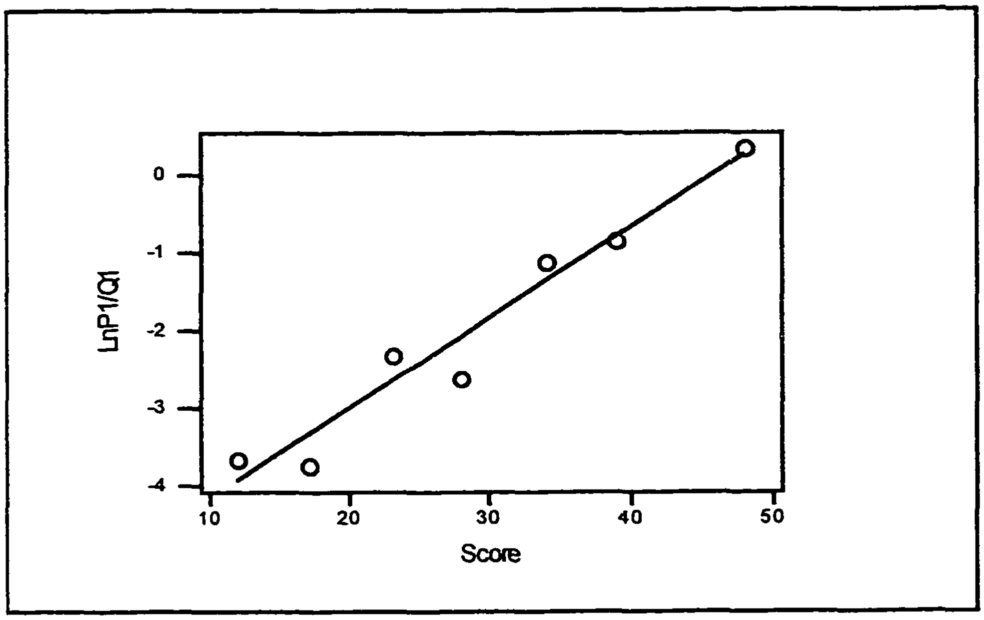

Figure 5.1 Evaluation of the injury risk score system. Plot of logit of observed proportion of injury among farmers interviewed in first year statewide survey (vertical axis) against composite scores (horizontal axis). Adjusted $R^2 = 94\%$.

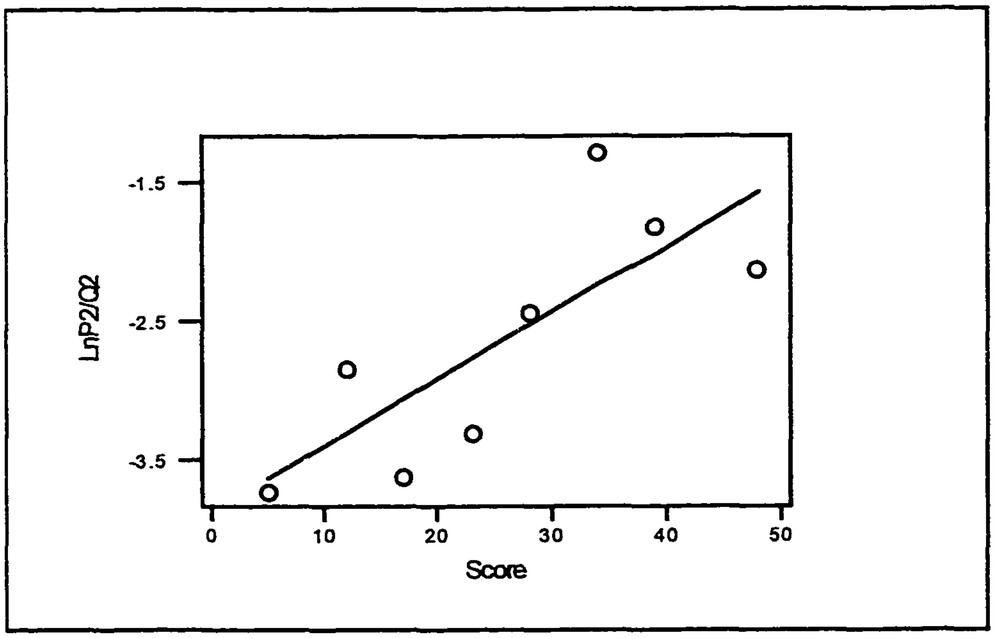

Figure 5.2 Evaluation of the injury risk score system. Plot of logit of observed proportion of injury among farmers interviewed in second year statewide survey (vertical axis) against composite scores (horizontal axis). Adjusted $R^2 = 55\%$.

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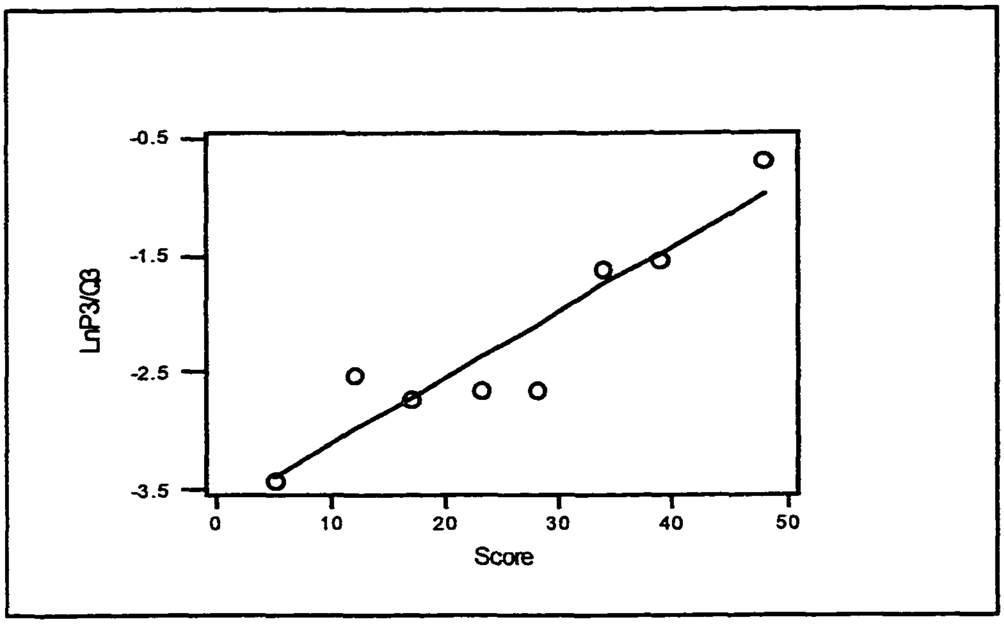

Figure 5.3 Evaluation of the injury risk score system. Plot of logit of observed proportion of injury among farmers interviewed in third year statewide survey (vertical axis) against composite scores (horizontal axis). Adjusted $R^2 = 85\%$.

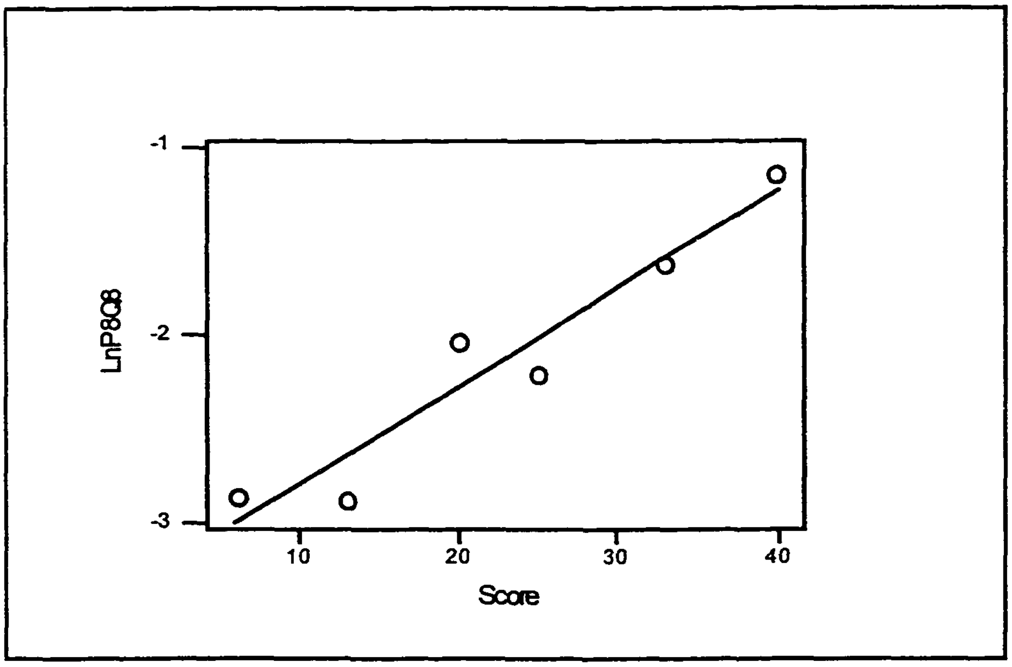

Figure 5.4 Evaluation of the injury risk score system. Plot of logit of observed proportion of injury among farmers interviewed in eight county survey (vertical axis) against composite scores (horizontal axis). Adjusted $R^2 = 90\%$.

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Then, straightline regression models were fitted to those graphs. The adjusted R^2 obtained from the first year of the statewide survey was 94%, which indicated that 94% of the variation in $\log_e(\frac{P}{1-P})$ was explained by the composite injury scores. The adjusted R^2 for the second year, the third year of the statewide survey and the eight county survey were 55%, 85%, and 90%, respectively.

The diagnostic tests of those straightline regression models (Figure 5.5-5.16) indicated that those straightline regression models described the linear relationships between $\log_e(\frac{P}{1-P})$ and composite injury risk scores well.

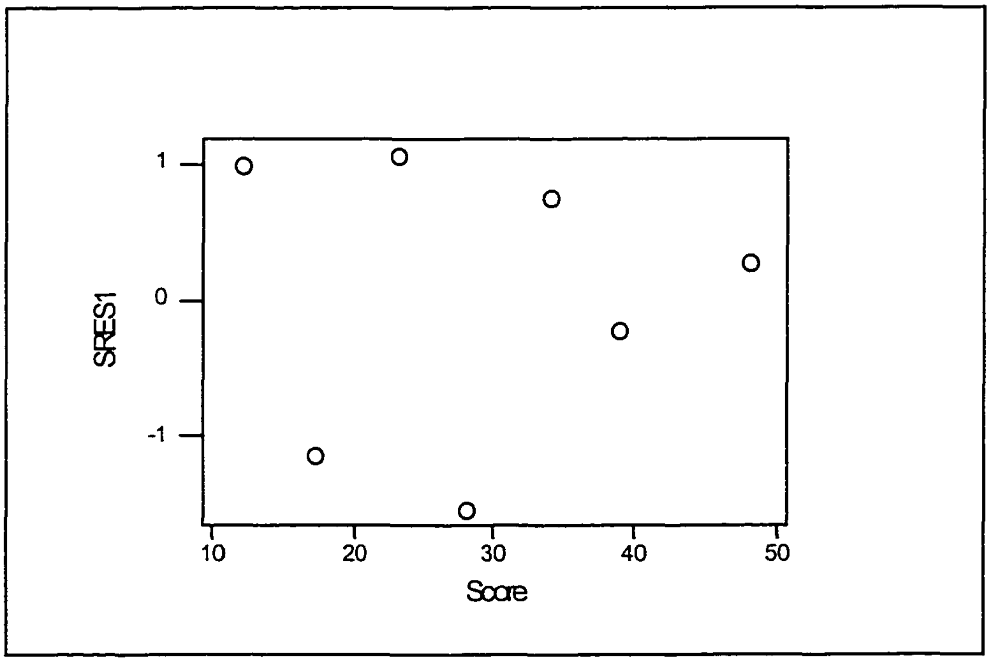

Figure 5.5 Diagnostic test (linearity) for the regression line of logit of observed injury among farmers interviewed in first year statewide survey against composite scores. Vertical axis - standardized residuals; horizontal axis - predictor score. Correlation coefficient = - 0.009.

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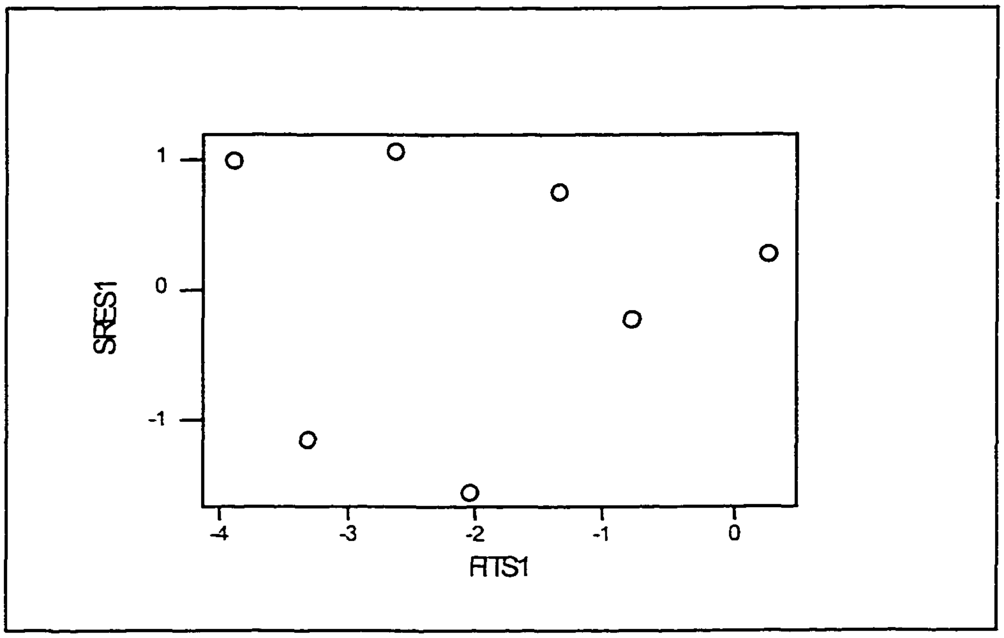

Figure 5.6 Diagnostic test (homogeneity) for the regression line of logit of observed injury among farmers interviewed in first year statewide survey against composite scores. Vertical axis - standardized residuals; horizontal axis - fits.

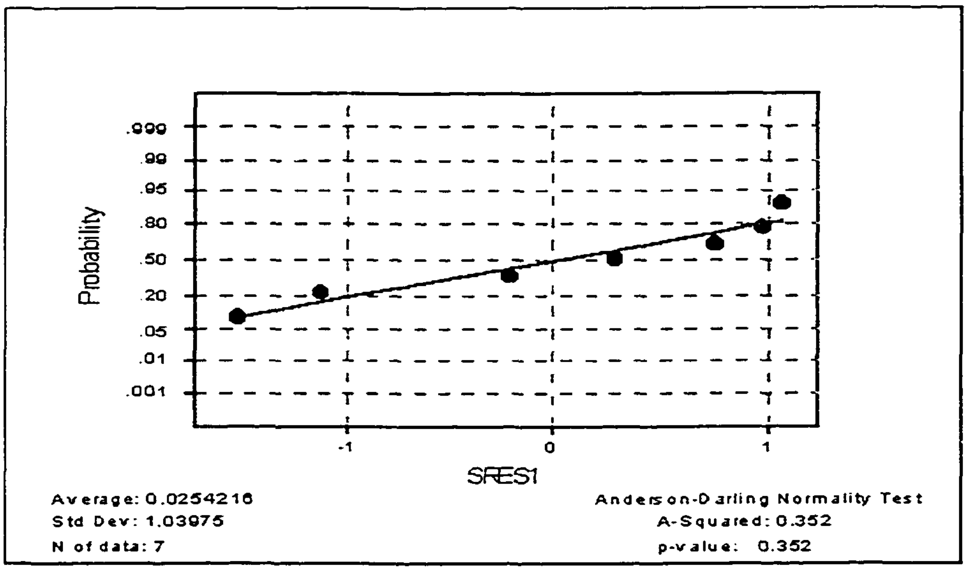

Figure 5.7 Diagnostic test (normal probability plot of standard residuals) for regression line of logit of observed injury among farmers interviewed in first year statewide survey.

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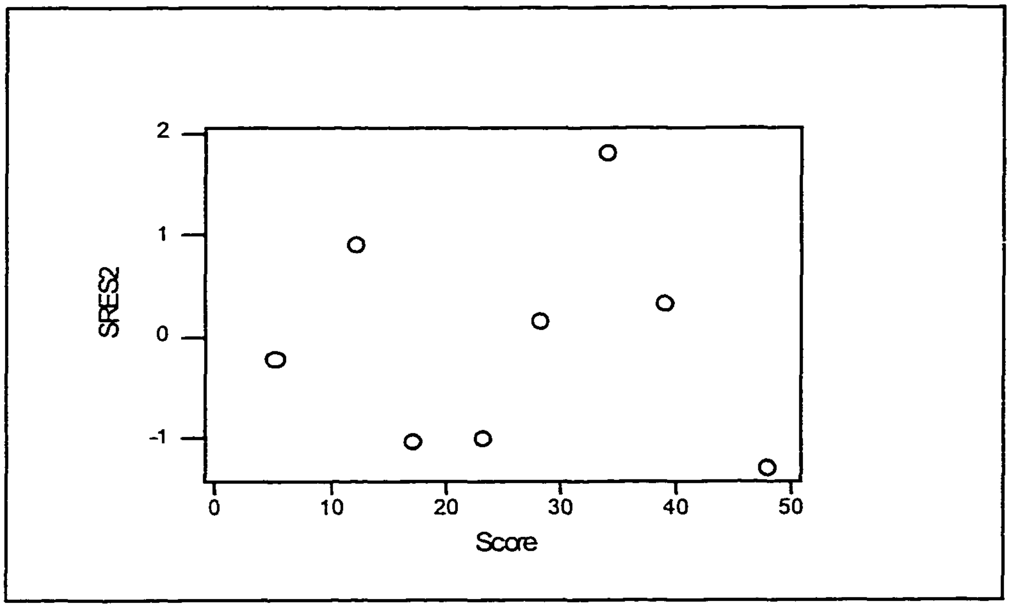

Figure 5.8 Diagnostic test (linearity) for the regression line of logit of observed injury among farmers interviewed in second year statewide survey against composite scores. Vertical axis - standardized residuals; horizontal axis - predictor score. Correlation coefficient = - 0.051.

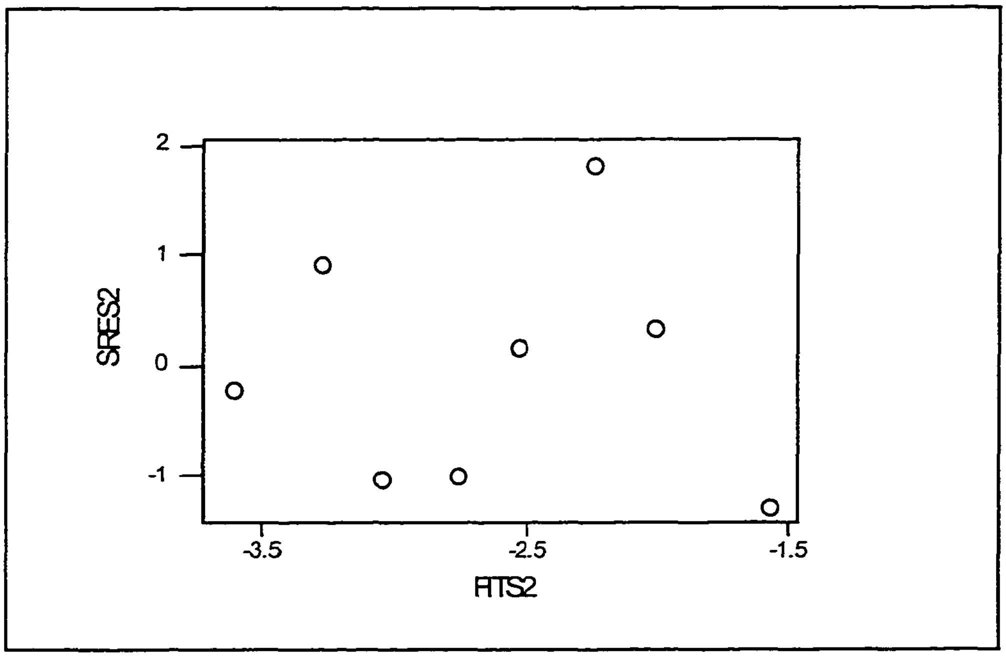

Figure 5.9 Diagnostic test (homogeneity) for the regression line of logit of observed injury among farmers interviewed in second year statewide survey against composite scores. Vertical axis - standardized residuals; horizontal axis - fits

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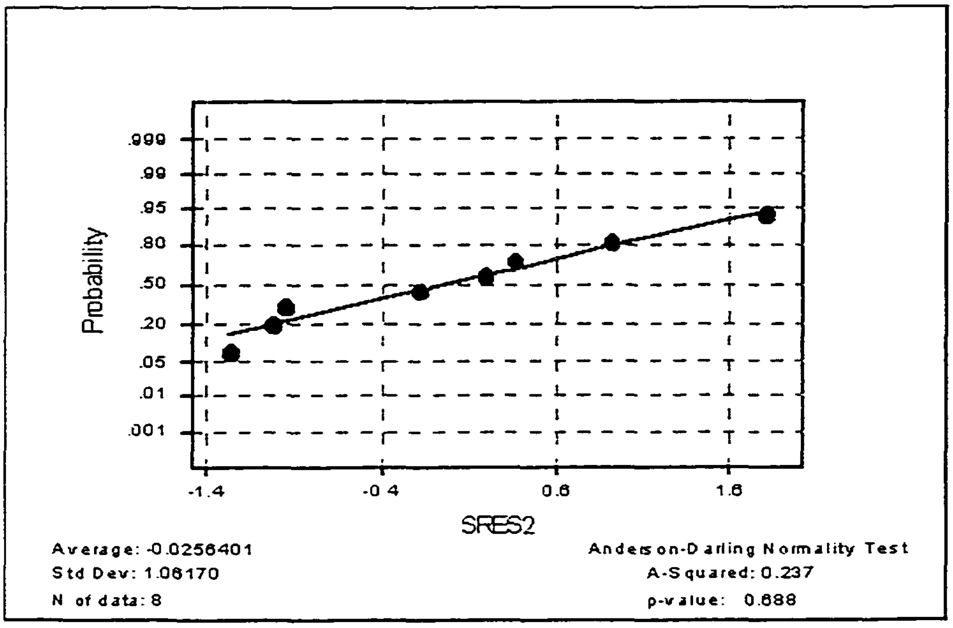

Figure 5.10 Diagnostic test (normal probability plot of standard residuals) for regression line of logit of observed injury among farmers interviewed in second year statewide survey.

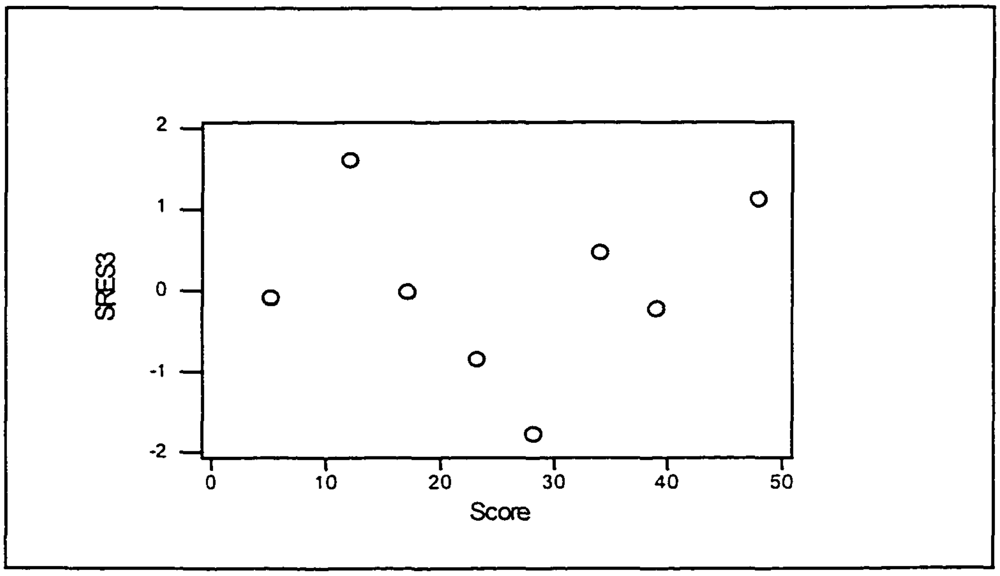

Figure 5.11 Diagnostic test (linearity) for the regression line of logit of observed injury among farmers interviewed in third year statewide survey against composite scores. Vertical axis - standardized residuals; horizontal axis - predictor score. Correlation coefficient = 0.038.

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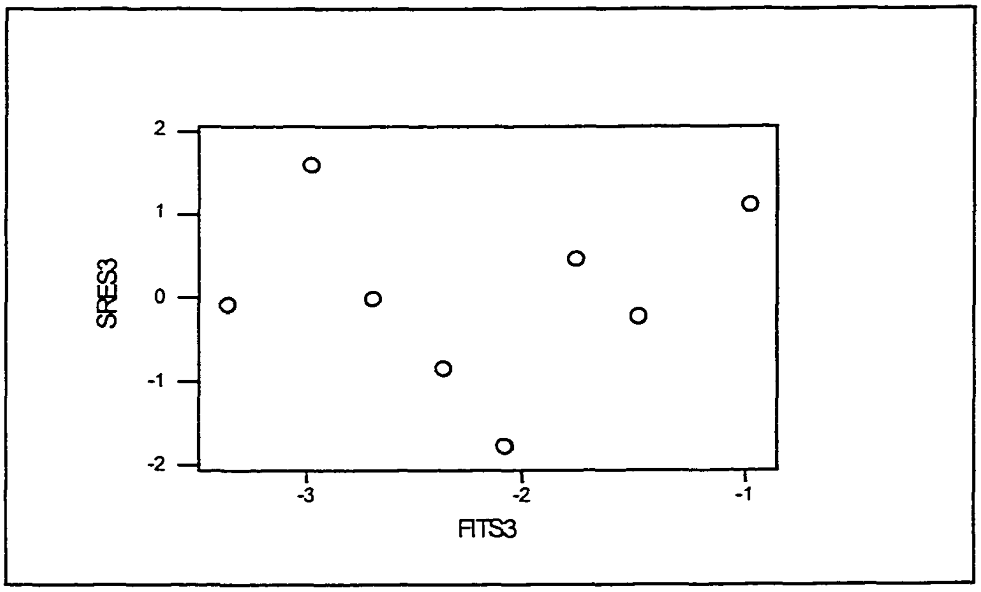

Figure 5.12 Diagnostic test (homogeneity) for the regression line of logit of observed injury among farmers interviewed in third year statewide survey against composite scores. Vertical axis - standardized residuals; horizontal axis - fits

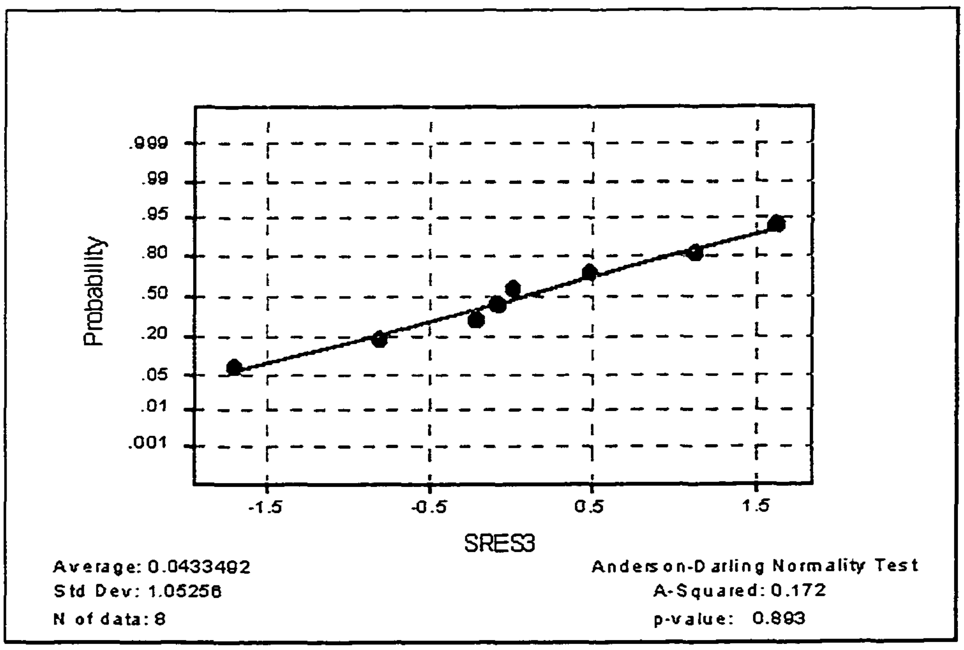

Figure 5.13 Diagnostic test (normal probability plot of standard residuals) for regression line of logit of observed injury among farmers interviewed in third year statewide survey.

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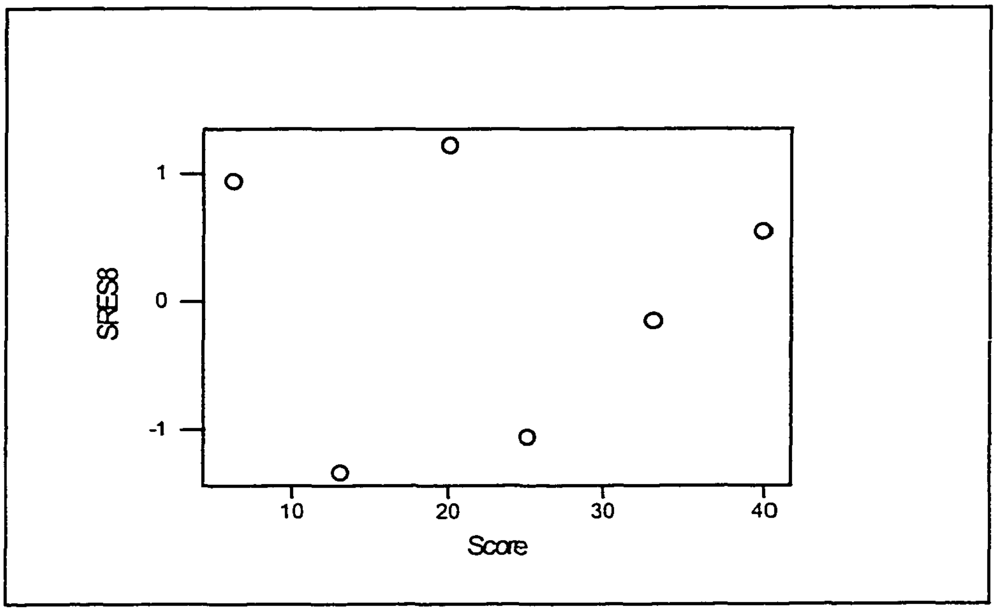

Figure 5.14 Diagnostic test (linearity) for the regression line of logit of observed injury among farmers interviewed in eight county survey against composite scores. Vertical axis - standardized residuals; horizontal axis - predictor score. Correlation coefficient = -0.009.

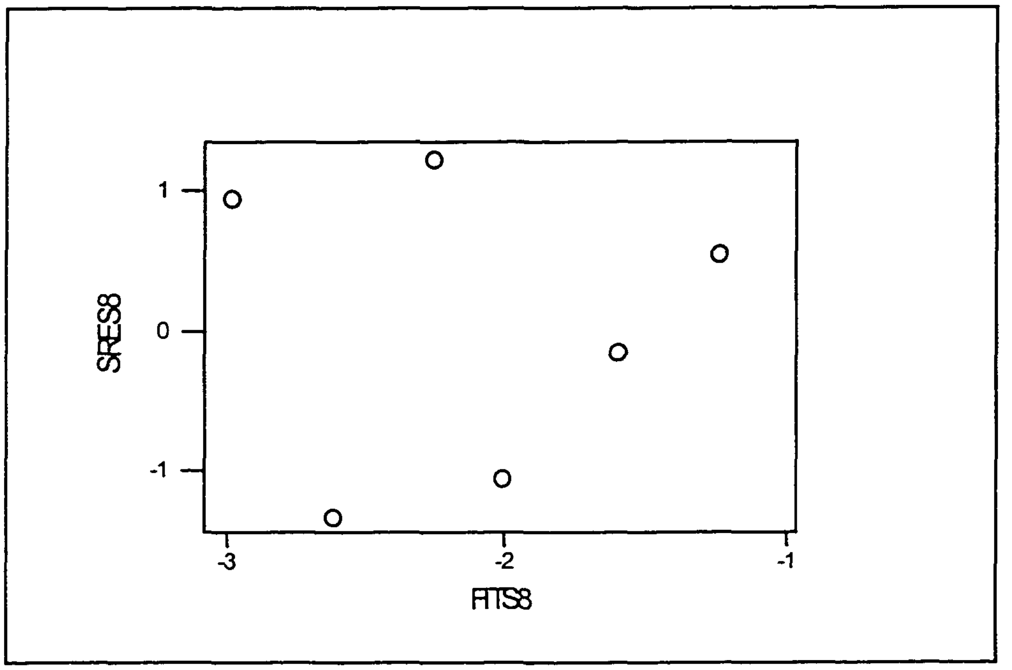

Figure 5.15 Diagnostic test (homogeneity) for the regression line of logit of observed injury among farmers interviewed in eight county survey against composite scores. Vertical axis - standardized residuals; horizontal axis - fits

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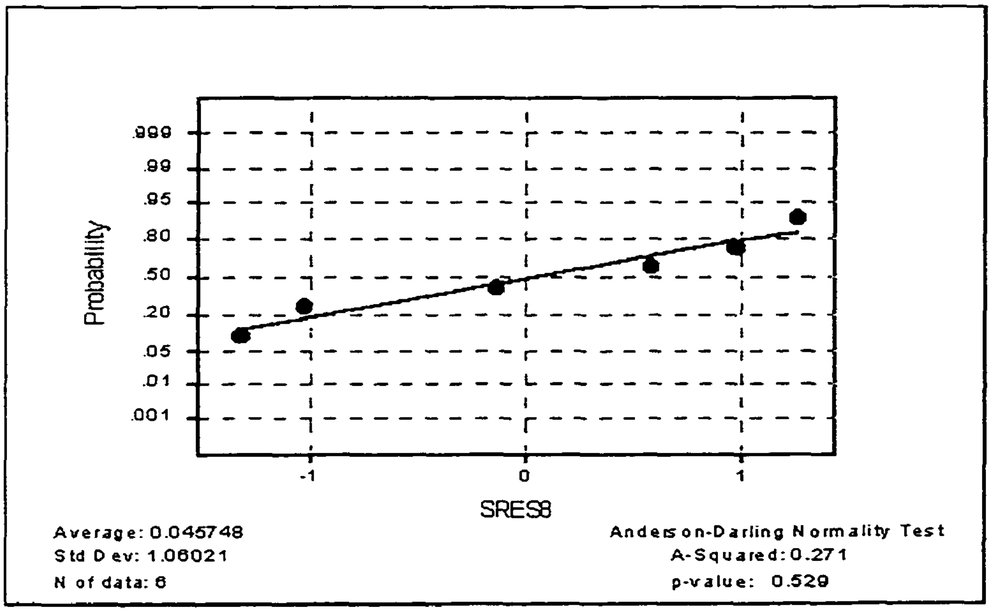

Figure 5.16 Diagnostic test (normal probability plot of standard residuals) for regression line of logit of observed injury among farmers interviewed in eight county survey.

5.6 Agricultural Injury Risk Prediction Worksheet

The data collected among farmers in the first year of the statewide survey, was used to created the agricultural injury risk prediction worksheet (Table 5.12).

First, the total injury risk score can be calculated using information from ten factors (age, gender, alcohol drinking, health status, back pain, occupation, primary farm products, paid days in off-farm employment, loss of sentimental things, legal problems).

Then, from the chart provided in Table 5.12, the risk probability of an agricultural work-related injury for a 12 month period can be determined. This agricultural injury prediction worksheet could be used to predict agricultural work-related injuries over a 12

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month period among farmers in Colorado.

Table 5.12 Agricultural injury (absolute) risk prediction worksheet (to be used in Colorado, U.S.A.).

1. Score each risk factor (number of points)

Age(yr)	**Points**	**Gender**	**Points**	**Alcohol use**	**Points**	**Health status**	**Points**	**Had back pain**	**Points**
20-29	9	Male	5	None or light	0	Excellent	0	Yes	10
30-39	9	Female	0	Moderate	8	Good	7	No	0
40-49	1			Heavy	6	fair or poor	12		
50-59	5								
60+	0								

Main occupation	**Points**	**Primary farm products**	**Points**	**Paid days worked off farm**	**Points**
Farming or ranching	7	Livestock (big animals- cattle or horses etc.)	4	None - 49	0
Other	0			50 - 149	10
		Livestock (small animals- Pigs, sheep, goats etc.)	12	150 +	0
		Other	0		

Lost something of sentimental value	**Points**	**Had legal problems**	**Points**
Yes	7	Yes	9
No	0	No	0

2. Add points for all risk factors: Total points __________

3. Read the risk for agricultural injury corresponding to the total points from the following nomogram:

Total Point	Risk	Total Point	Risk	Total Point	Risk	Total Point	Risk	Total Point	Risk
0	0.005	12	0.019	24	0.074	36	0.246	48	0.571
1	0.005	13	0.022	25	0.083	37	0.268	49	0.599
2	0.006	14	0.024	26	0.092	38	0.292	50	0.627
3	0.007	15	0.027	27	0.102	39	0.317	51	0.654
4	0.008	16	0.031	28	0.113	40	0.343	52	0.680
5	0.009	17	0.034	29	0.126	41	0.370	53	0.705
6	0.010	18	0.038	30	0.139	42	0.397	54	0.729
7	0.011	19	0.043	31	0.154	43	0.426	55	0.751
8	0.012	20	0.048	32	0.170	44	0.454	56	0.772
9	0.014	21	0.053	33	0.187	45	0.484	57	0.792
10	0.015	22	0.060	34	0.205	46	0.513	58	0.811
11	0.017	23	0.067	35	0.225	47	0.542	59	0.828

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CHAPTER VI

DISCUSSION

Thorough discussion of the characteristics of agricultural work-related injuries and associated risk factors among farmers interviewed by the CFFHHS have been described in several previous publications (Stallones et al., 1997; Xiang et al., 1998, 1999). The discussion here will focus on composite injury risk score system and its application in injury control programs. Readers who are interested in more detailed results about characteristics of agricultural injuries and the associated risk factors among this sample of Colorado farmers can refer to the attached publications (Appendix VI).

This study demonstrated that a simple injury risk score, based on demographics of farmers, farming activities, and negative life events, is a reliable and valid tool for predicting risk of agricultural work-related injuries. The good correspondence of results in the cross-validation study also demonstrated that the injury risk score system can provide predictive evaluation of work-related injury risk even when it was used for a different population.

The concept of injury predictability and preventability is a conceptual breakthrough which occurred in the past several decades in the injury control and prevention field. For many generations, the word "accident" suggested an event that took places without foresight or expectations (Waller, 1994; Bijur, 1995; Loimer et al., 1996). Injury events have tended to be attributed to human error or misaction. With the advent of the

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industrialization in the nineteenth century, environmental risk factors for injury became more discernable, and challenges of "accident prevention" and industrial safety began to receive sustained attention. In the past two decades, the prevailing opinion in the public health community was that use of the word "accident" was detrimental to injury control and prevention efforts (Bijur, 1995; Loimer et al., 1996). While decades of research have made it clear that there are seasonal, geographic, epidemic, and demographic variations in the occurrence of injuries, such events as a group are substantially nonrandom.

Epidemiologic surveys have typically focused on the nature and extent of work-related injuries with aims of identifying occupational groups who are at high risk and might benefit from prevention activities (Courtney et al., 1999). Studies were based upon one central axiom, that injury is not randomly distributed in human populations. Injury shows aggregations in time, in space, and according to measurable human traits. This aggregations result in variations in the risk of injury. Variations in risk of injury are manifestations of variations in individual exposures or in individual susceptibility to causative factors.

Although descriptive epidemiology of injuries and safety engineering studies have been reported for decades (Stallones, 1963; Manheimer et al., 1967; Haddon, 1973; Waller, 1985; Waller, 1994; Loimer et al., 1996; Victora et al., 199; NIOSH, 1997; Stallones et al., 1997; Lewis et al., 1998; Xiang et al., 1998, 1999), improved prevention efforts will require new methodological approaches (NIOSH, 1998). Suchman and Scherzer (1960) have suggested that injuries should be studied as a phenomena reflecting a balance between subjective assessment of the probability of injury and risk-taking

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behavior. Accordingly, prevention might be achieved by reducing injury potential of the environment, by increasing accuracy of judgement of probability of an injury, or by decreasing people's willingness to take chances (Stallones, 1963).

Composite risk scale systems have made a large contribution to the measurement of a complex health phenomena, such as disease risk (Coste et al., 1996, 1997). However, the construction of such a risk scale involves complex procedures, and an appropriate methodology is required. The proposed injury risk score system presented in this study was a compromise between simplicity of designating high-risk and low-risk subgroups and the accuracy of detailed logistic regression models. High-risk and low-risk classifications are appealing because the classification scheme is easy to remember and because assignment to such groups often has implications for risk management. The drawback of this approach is the oversimplification caused by dividing a large and diverse cohort of the population into two theoretically homogeneous subgroups. On the other hand, regression models are often too complex to be used in intervention programs, especially by lay people. The composite injury risk scores used in this study were based on logistic regression coefficients which were further simplified such that they can be computed without a calculator, and the risk of injury is directly read from a nomogram without further computation. The injury risk score incorporated information from the majority of independent risk factors, and it could either be used to assign farmers into high-, moderate-, or low-risk groups if desired, or be used to provide continuous risk probability measure.

It should be noted that alcohol use was self-reported by farmers in this study.

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Alcohol use was measured with a combination of four questions: quantity, frequency, usual type of alcohol consumed, and occasional binge drinking. Binge drinking was defined as five drinks in a row during the past month. Using an alcohol use cross-classification system developed by Lipton (1994), farmers were classified as "none or light drinkers", "moderate drinkers", or "heavy drinkers" according to their level of alcohol consumption. It is noteworthy that social desireability may play a role in farmers' response to these questions in that heavier drinkers could report artificially low levels of intake (Lipton, 1994). Also, because the classification of alcohol drinkers was based on four questions, there was a potential for misclassification in this study. Hence, conclusion on attributable risk of alcohol among those injured farmers was preliminary. The counterintuitive result that moderate drinkers had a higher injury risk (OR = 2.02; 95% CI = 0.68 - 6.02) than heavy drinkers (OR=1.69; 95% CI = 0.99 - 2.88) suggests that there might be misclassification of alcohol users or other unidentified variables which might confound the observed relationship between injuries and alcohol. Although alcohol has been recognized as a problem in the work place since 1940s, there have been few studies which document precisely the magnitude of the problem nor exact contribution of alcohol to the occurrence of injuries (Stallones et al., 1993). Analytic studies which have better measurement of alcohol consumption or use and which assess confounding variables are needed so as to aid in the design of effective countermeasure strategies (Stallones et al., 1993).

The public health approach to injury prevention in the workplace includes three elements: assessment, development of prevention strategies, and evaluation. Central to

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this approach is a surveillance system that is capable of providing essential information for each of these elements (Bonnie et al., 1999). One of the priorities in the occupational injury prevention researches is risk communication (NIOSH, 1998). If knowledge of risks exists, then dissemination of prevention information may improve both organizational and individual decision-making in hazardous situations. From an injury prevention standpoint, the question we asked here is "what characteristics do farmers have that increase their probability of having agricultural work-related injuries?" The findings reported in this paper should help to answer this important question and, in so doing, aid in identifying farmers who are especially likely to have work-related injuries, without waiting for the injuries to occur. This information will be very useful in designing injury prevention strategies(NIOSH, 1998).

Verification of model relevance have been performed in this study. A variety of methods were used, from graphic methods such as examination of "diagnostic plots" to statistics based on comparison of observed and predicted values. According to several researchers (Coste et al., 1997), the best approach of cross-validation is to perform independent studies at different times or in different settings. We assessed the validation of our injury risk score system using the second and third year of the statewide survey and the data collected from eight county area, and found good correspondences of results in cross-validation study except for second year statewide data. In order to find clues for the failed cross-validation in second year statewide data, the days between the first interview and the second year follow-up interview were calculated. According to the study design, those 872 farmers interviewed in the first year statewide survey should be

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followed up 12 months (365 days) later. However, our results (Figure 6.1) indicated that the average interval between the first interview and the second interview in the statewide survey was 329 days, significantly less than the average interval (367 days) between the second interview and the third interview. The relatively shorter period between the first interview and the second interview might partially explain why the injury rate among farmers interviewed in the second year of the statewide survey (7.4%) was much lower than the injury rates in other years (11.5% for first year and 9.2% for third year) or in different settings (11.2% for the eight county survey).

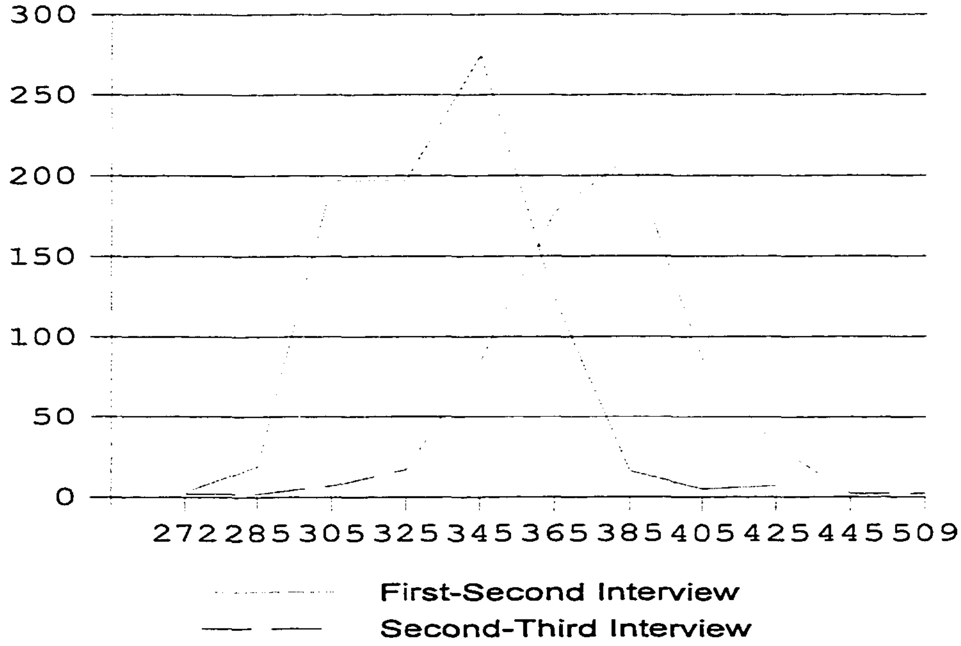

Figure 6.1 Days between different interviews in statewide follow up surveys, Colorado Farm Family Health and Hazard Surveillance, 1993-1995.

Other reasons, such as major farming activity changes during the year, or farmers behavior modification because of the exposure to the "educational period" through

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participating in the CFFHHS project, might also be plausible explanations for the poor performance of the prediction methods in the second year statewide data.

In order to evaluate changes in our study population, the characteristics of different study cohorts in the CFFHHS project with respect to the ten variables used in the construction of the injury risk scores were compared (Table 6.1). The results from comparisons indicated that the second and third year statewide data were statistically different from the first year statewide data regarding back pain, main duties on farm, primary farm products, and loss of things of sentimental value. A lower percentage of farmers reported to have those potential injury risk factors in the second and the third year of the statewide survey. When data from the eight county survey were compared to the first year statewide data, it also showed that the study cohort from the eight county survey was statistically different from the cohort of the first year of the statewide survey with respect to age distribution, gender, health status, back pain, main duty on the farm, and the primary farm production. However, a higher percentage of farmers in the eight county survey had potential injury risk factors of gender, health status, back pain, and main duties on the farm. The fact that fewer people in the second and third year of the statewide survey had potential risk factors for injury could be used as an explanation for the lower injury rates observed in the second and third year of the statewide survey. But, whether this was also the reason for the poor predictability of our injury risk score system in the second year of statewide survey was not clear, especially since the injury score system had good performance in the third year of the statewide survey or in the eight county survey.

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Table 6.1. Comparison of Different Study Cohorts by the Ten Variables Included in the Final Prediction Models, Colorado Farm Family Health and Hazard Surveillance project, 1993-1996.

Characteristics	Statewide Survey First Year No. (%)	Statewide Survey Second Year No. (%)	Statewide Survey Third Year No. (%)	Eight County Survey No. (%)
Age in years				
20-29	29 (6.8)	38 (5.1)	26 (4.4)	23 (3.0)
30-39	206 (23.6)	176 (23.6)	140 (23.6)	147 (19.4)
40-49	238 (27.3)	212 (28.5)	180 (30.3)	218 (28.8)
50-59	196 (22.5)	161 (21.6)	127 (21.4)	161 (21.3)
60+	173 (19.8)	158 (21.2)	121 (20.4)	208 (27.5)**
Gender				
Male	470 (53.9)	385 (51.6)	303 (51.0)	459 (60.4)**
Female	402 (46.1)	361 (48.4)	291 (49.0)	301 (39.6)
Alcohol drinking				
None/light	510 (59.7)	325 (43.8)	285 (43.7)	350 (46.5)
Moderate	227 (26.5)	290 (39.1)	261 (40.0)	282 (37.5)
Heavy	118 (13.8)	127 (17.1)	106 (16.3)	121 (16.1)
Health Status				
Excellent	281 (32.2)	237 (31.8)	198 (30.4)	196 (25.8)
Good	530 (60.9)	447 (60.0)	401 (61.5)	520 (68.4)**
Fair or poor	60 (6.9)	61 (8.2)	53 (8.1)	44 (5.8)
Had back pain				
Yes	92 (10.6)	44 (5.9)**	38 (5.8)**	196 (25.9)**
No	779 (89.4)	701 (94.1)	615 (94.2)	560 (74.1)
Main duty				
Farming/ ranching	430 (49.4)	343 (46.0)	264 (40.6)**	428 (56.5)**
Other	441 (50.6)	402 (54.0)	387 (59.5)	330 (43.5)
Primary farm products				
Livestocks	376 (43.2)	187 (25.1)**	143 (21.9)**	242 (31.8)**
Other	495 (56.8)	559 (74.9)	510 (78.1)	519 (68.2)
Off-farm paid employments				
50 - 149 days	91 (10.5)	82 (11.0)	61 (9.3)	75 (10.0)
Other	778 (89.5)	663 (89.0)	592 (90.7)	679 (90.0)
Lost something of sentimental value				
Yes	154 (17.7)	82 (11.0)**	68 (10.4)**	112 (14.9)
No	716 (82.1)	663 (89.0)	585 (89.6)	641 (85.1)
Had legal problems				
Yes	63 (7.2)	41 (5.5)	42 (6.4)	43 (5.7)
No	806 (92.4)	704 (94.5)	611 (93.6)	710 (94.3)

Note: Study cohorts were compared with first year statewide study cohort; ** significantly different (P<0.05)

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An important condition for cross-validation of the injury risk score is large data sets which can be used to obtain reliable observed proportions of injury among farmers to provide an opportunity to compare predicted values with observed values (Coste et al., 1997). Because injury is a relatively rare outcome (around 10% among farmers in this study), a large data set is essential in the cross-validation of the injury risk score system. However, the sample size used by the CFFHHS project was relatively small. Therefore, the findings here should be interpreted with caution. Furthermore, the injury risk score was developed using data collected among Colorado farmers without cross-validation in agricultural settings in other states. It might be reasonable to assume that farmers in other states have different characteristics and are involved in different farming activities. So the injury risk score system presented here is a preliminary method which warrants further evaluation among farmers in other states or in larger samples of Colorado farmers.

Another limitation of the injury risk score system is the assumption that all of the variables used in the final logistic regression models will stay relatively stable, which means that the agricultural work-related injury patterns will repeat over time or in different settings. However, the relationship between any population of workers and their environment is dynamic, changing over time (Hagberg et al., 1997). Exposures vary over time, the workplace physical setting varies over time, the workforce ages, individuals alter personal habits, and individuals develop concomitant medical conditions that may alter their injury risk (Hagberg et al., 1997). Unfortunately, no model which can incorporate all of these factors in the development of an injury risk score system. So there were definitely variations left in injury risk which are not be accounted for by any

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model.

However, even with the above limitations, results here suggest that the constructed composite injury risk score system which was developed to predict the probability of agricultural work-related injury among Colorado farmers had good predictive ability, satisfactory content and good validity and reliability. In addition, it would be easy to use in injury control and prevention programs. Future efforts to further evaluate this system, improve the methods, and determine validity and reliability over time are needed. Further, the utility of the injury risk score system needs to be evaluated after it has been used to design injury control and prevention programs among Colorado farmers.

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Appendix I

Final Logistic Regression Model

Data Set: WORK.INJURY
Response Variable: WRINJURY
Response Levels: 2
Number of Observations: 856
Link Function: Logit

Response Profile

Ordered Value	WRINJURY	Count
1	1	78
2	0	778

WARNING: 16 observation(s) were deleted due to missing values for the response or explanatory variables.

Model Fitting Information and Testing Global Null Hypothesis BETA=0

Criterion	Intercept Only	Intercept and Covariates	Chi-Square for Covariates
AIC	524.374	491.149	.
SC	529.126	571.938	.
-2 LOG L	522.374	457.149	65.225 with 16 DF (p=0.0001)
Score	.	.	68.734 with 16 DF (p=0.0001)

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Analysis of Maximum Likelihood Estimates

Variable	DF	Parameter Estimate	Standard Error	Wald Chi-Square	Pr > Chi-Square	Standardized Estimate	Odds Ratio
INTERCPT	1	-4.8041	0.5382	79.6837	0.0001	.	.
AGE1	1	0.8078	0.5333	2.2941	0.1299	0.111991	2.243
AGE2	1	0.8094	0.3982	4.1323	0.0421	0.189583	2.246
AGE3	1	0.0781	0.4265	0.0335	0.8548	0.019296	1.081
AGE4	1	0.4595	0.4172	1.2131	0.2707	0.105924	1.583
GENDER	1	0.4520	0.3102	2.1234	0.1451	0.124350	1.571
OCCUPAT1	1	0.6703	0.2964	5.1134	0.0237	0.184864	1.955
HEALTH2	1	0.6315	0.3214	3.8596	0.0495	0.170020	1.880
HEALTH3	1	1.0959	0.5033	4.7408	0.0295	0.150722	2.992
BACKPAIN	1	0.9272	0.3301	7.8886	0.0050	0.156885	2.527
LOST96A	1	0.6252	0.2904	4.6338	0.0313	0.132146	1.869
LEGAL96I	1	0.8534	0.3973	4.6148	0.0317	0.121119	2.348
ALCOHOL2	1	0.7015	0.5585	1.5779	0.2091	0.075583	2.017
ALCOHOL3	1	0.5245	0.2720	3.7179	0.0538	0.131107	1.690
CASHCRP2	1	0.3542	0.2610	1.8422	0.1747	0.095469	1.425
CASHCRP3	1	1.1187	0.5531	4.0916	0.0431	0.120531	3.061
PAIDEMP2	1	0.9342	0.3326	7.8902	0.0050	0.158070	2.545

Association of Predicted Probabilities and Observed Responses

Concordant	= 74.3%	Somers' D	= 0.496
Discordant	= 24.7%	Gamma	= 0.501
Tied	= 1.0%	Tau-a	= 0.082
(60684 pairs)		c	= 0.748

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The LOGISTIC Procedure

Conditional Odds Ratios and 95% Confidence Intervals

Variable	Unit	Odds Ratio	Wald Confidence Limits Lower	Upper
AGE1	1.0000	2.243	0.789	6.379
AGE2	1.0000	2.246	1.029	4.902
AGE3	1.0000	1.081	0.469	2.494
AGE4	1.0000	1.583	0.699	3.586
GENDER	1.0000	1.571	0.856	2.886
OCCUPAT1	1.0000	1.955	1.093	3.495
HEALTH2	1.0000	1.880	1.001	3.531
HEALTH3	1.0000	2.992	1.116	8.024
BACKPAIN	1.0000	2.527	1.323	4.827
LOST96A	1.0000	1.869	1.058	3.302
LEGAL96I	1.0000	2.348	1.078	5.115
ALCOHOL2	1.0000	2.017	0.675	6.027
ALCOHOL3	1.0000	1.690	0.991	2.880
CASHCRP2	1.0000	1.425	0.854	2.377
CASHCRP3	1.0000	3.061	1.035	9.050
PAIDEMP2	1.0000	2.545	1.326	4.884

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Appendix II

Straightline Regression Model (Logit of Proportion of Injury vs. Injury Risk Scores)
First Year Statewide Survey

The regression equation is
LnP1/Q1 = - 5.33 + 0.117 Score

Predictor	Coef	Stdev	t-ratio	p
Constant	-5.3317	0.3711	-14.37	0.000
Score	0.11701	0.01197	9.77	0.000

s = 0.3700   R-sq = 95.0%   R-sq(adj) = 94.0%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	13.080	13.080	95.54	0.000
Error	5	0.685	0.137		
Total	6	13.765			

Straightline Regression Model (Logit of Proportion of Injury vs. Injury Risk Scores)
Second Year Statewide Survey

The regression equation is
LnP2/Q2 = - 3.86 + 0.0478 Score

Predictor	Coef	Stdev	t-ratio	p
Constant	-3.8642	0.4491	-8.60	0.000
Score1	0.04776	0.01546	3.09	0.021

s = 0.5882   R-sq = 61.4%   R-sq(adj) = 55.0%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	3.3018	3.3018	9.54	0.021
Error	6	2.0756	0.3459		
Total	7	5.3773			

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Straightline Regression Model (Logit of Proportion of Injury vs. Injury Risk Scores)
Third Year Statewide Survey

The regression equation is
LnP3/Q3 = - 3.66 + 0.0560 Score

Predictor	Coef	Stdev	t-ratio	p
Constant	-3.6604	0.2587	-14.15	0.000
Score1	0.056029	0.008905	6.29	0.001

s = 0.3388 R-sq = 86.8% R-sq(adj) = 84.6%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	4.5441	4.5441	39.59	0.001
Error	6	0.6887	0.1148		
Total	7	5.2327			

Straightline Regression Model (Logit of Proportion of Injury vs. Injury Risk Scores)
Eight County Survey

The regression equation is
LnP8/Q8 = - 3.31 + 0.0519 Score

Predictor	Coef	Stdev	t-ratio	p
Constant	-3.3065	0.1951	-16.95	0.000
Score	0.051865	0.007634	6.79	0.002

s = 0.2147 R-sq = 92.0% R-sq(adj) = 90.0%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	2.1273	2.1273	46.16	0.002
Error	4	0.1844	0.0461		
Total	5	2.3117			

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Appendix III

Comprehensive Listing of Variables Considered in Univariate and Multivariate Analyses: Colorado Farm Family Health and Hazard Surveillance, 1993-1996

Demographic and socio-economic variables and construct	Farm characteristic variables and construct	Work practice behavioral risk variables and construct	Negative life events, physical and emotional variables
Age in years	Annual sales value of	Occupation(primary duties)	Lost something of
<30	all products	Farming or ranching	sentimental value
30-39	0-39 thousand	Homemaking	Yes, no
40-49	40-99 thousand	Student	
50-59	100+ thousand	Other	Close friend died
60+			Yes, no
	Primary cash products		
Gender	Field and crop production		Divorced or
Male	Livestock (beef cattle,	Days worked unrelated to	separated
Female	dairy, feedlot)	the operation of the farm	Yes, no
	Livestock (sheep, hogs,	in the past year	
	goats	0 - 49	Trouble with in-
Marital status	Other(forest, vegetable	50 - 149	laws
Married	melon, fruit, nut)	150+	Yes, no
Other			
	Herbicides used on the farm	Worked on someone else'	Spouse died
Years in school	Yes, no	farm or ranch during the	Yes, no
12 or less		past 12 months	
13 - 15	Crop insecticides used	Yes, no	Family member
16 or more	Yes, no		died
		Years involved in	Yes, no
Race	Insecticides used on livestock	agricultural work	
White	Yes, no	0 - 9	Income decreased
Other		10 - 29	substantially
	Acres in use	30 +	Yes, no
Ever smoked	≤500		
Yes, no	500+	Use seat belt when	Gone deeply into
		drive or ride a car	debt
Current smoker		Always	Yes, no
Yes, no		Sometimes	
		Never	

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Appendix III (continue). Comprehensive Listing of Variables Considered in Univariate and Multivariate Analyses: Colorado Farm Family Health and Hazard Surveillance, 1993-1996

Demographic and socio-economic variables	Negative life events, physical and emotional variables
Years smoked	Had legal problems
None	Yes, no
1 - 10	
11- 20	Been assaulted
21+	Yes, no
Average cigarettes smoked per day	Had depression **
0	Yes, no
1 - 10	
11- 20	Health Status
	Excellent
	Very good or good
Level of alcohol drink *	Fair or poor
None or light	
Moderate	Back pain
Heavy	Yes, no
	Arthritis
	Yes, no
	Hearing loss
	Yes, no
	High blood pressure
	Yes, no

*: None or light — drink alcohol 0 - 4 days per month.
Moderate — drink alcohol 5-25 days with no more than 2 drinks each time.
Heavy — drink alcohol 5-25 days with more than 2 drinks each time or drink alcohol more than 25 days per month.

**: Depression status were determined using the Center for Epidemiologic Studies Depression (CESD) Scale, which contains a series of 20 psychosocial questions.

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Appendix IV

Coding Format of Selected Variables Used in the Multiple Logistic Regression Models, Colorado Farm Family Health and Hazard Surveillance, 1993-1996

Characteristics	Variable and Coding	
Age in years	age	
<30		age1
30-39		age2
40-49		age3
50-59		age4
60+		age5
Gender	gender	
Male		1
Female		0
Health Status	health	
Excellent		health1
Very good or good		health2
Fair of poor		health3
Backpain	backpain	
Yes		1
No		0
Lost something of sentimental value	lost96a	
Yes		1
No		0
Had legal problems	legal96i	
Yes		1
No		0
Occupation	occupatn	
Farming or ranching		occupat1
Home making		occupat2
Student		occupat3
Other		oocupat4

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Appendix IV (continue). Coding Format of Selected Variables Used in the Multiple Logistic Regression Models: Colorado Farm Family Health and Hazard Surveillance, 1993-1996

Characteristics	Variable and Coding	
Primary cash products	cashcrop	
Field and crop production		cashcrp1
Livestock (beef cattle, dairy, feedlot)		cashcrp2
Livestock (sheep, hogs, goats)		cashcrp3
Other (forest, vegetable, melon, fruit, nut)		cashcrp4
Off-farm paid employment (days per year)	paidemp	
None-49		paidemp1
50-149		paidemp2
150+		paidemp3
Level of alcohol drink		
None or light		alcohol1
Moderate		alcohol2
Heavy		alcohol3

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Appendix V

Fortrann 77 Program for Scaling and Rounding Regression Coefficients to Integers

(Subroutine was developed by T.J. Cole.)

```
C---------------------------------------------C
      PROGRAM SRREG
C
C This program will scale and round regression
C coefficients to integers by calling SUBROUTINE RCINT
C
      INTEGER N,L,M,NS
C
      PARAMETER (N = 16, L=16, M =100)
      DOUBLE PRECISION RC(16), WT(16), X(16,16), WORK2(16), WORK(3,M),
     * Y(L)
      RC(1) = 0.8078
      RC(2) = 0.8094
      RC(3) = 0.0781
      RC(4) = 0.4595
      RC(5) = 0.4520
      RC(6) = 0.6315
      RC(7) = 1.0959
      RC(8) = 0.6703
      RC(9) = 0.9272
      RC(10)= 0.6252
      RC(11)= 0.8534
      RC(12)= 0.7015
      RC(13)= 0.5245
      RC(14)= 0.3542
      RC(15)= 1.1187
      RC(16)= 0.9342
C
C
      WT(1) = 1 / (0.5333*0.5333)
      WT(2) = 1 / (0.3982*0.3982)
      WT(3) = 1 / (0.4265*0.4265)
      WT(4) = 1 / (0.4172*0.4172)
      WT(5) = 1 / (0.3102*0.3172)
      WT(6) = 1 / (0.3214*0.3214)
      WT(7) = 1 / (0.5033*0.5033)
```


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```
      WT(8) = 1 / (0.2964*0.2964)
      WT(9) = 1 / (0.3301*0.3301)
      WT(10)= 1 / (0.2904*0.2904)
      WT(11)= 1 / (0.3973*0.3973)
      WT(12)= 1 / (0.5585*0.5585)
      WT(13)= 1 / (0.2720*0.2720)
      WT(14)= 1 / (0.2610*0.2610)
      WT(15)= 1 / (0.5531*0.5531)
      WT(16)= 1 / (0.3326*0.3326)
C
C
C
      DO 3 I=1, 16
        DO 2 J=1, 16
          IF (I.EQ.J) THEN
            X(I,J) = 1.0
          ELSE
            X(I,J) = 0.0
          END IF
 2        CONTINUE
 3      CONTINUE
C
C
C
C
C
      CALL RCINT(N,RC,L,X,WT,Y,M,WORK,NS,WORK2)
C
C
C
      WRITE (*,*) N,L,M
        WRITE (*,*) NS
C
       OPEN (UNIT = 1, FILE ='/n/hyxiang/scout')
       DO 8 I=1, NS
        WRITE(1,*) WORK(1,I),WORK(2,I)
 8      CONTINUE
C
C
C
      END

C-----------------------------------------------------------C
      SUBROUTINE RCINT(N, RC, L, X, WT, Y, M, WORK, NS, WORK2)
C
C ALGORITHM AS 281.1 APPL. STATIST. (1993) VOL.42, NO.1
C
C Scaling and rounding regression coefficients to integers
C
      INTEGER N, L, M, NS
C
```


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```
      IMPLICIT DOUBLE PRECISION(A-H, O-Z)
C
C
      DOUBLE PRECISION RC(N), X(N,L), WT(L), Y(L), WORK(3,M), WORK2(N)
C
C
C
      LOGICAL OK
C
C
      EXTERNAL RCINT2
C
      DATA ZERO, EPS, HALF, BIG / 0D0, 1D-8, 0.5D0, 1D8 /
C
C
C
C
      NS = 0
      NRC = 0
      SCMIN = BIG
      RCSUM = ZERO
      DO 10 I = 1, N
        RCT = ABS ( RC(I) )
        IF ( RCT .EQ. ZERO ) GO TO 10
        NRC = NRC + 1
        RCSUM = RCSUM + RCT
        IF ( RCT .LT. SCMIN ) SCMIN = RCT
10    CONTINUE
      IF ( NRC .EQ. 0 ) RETURN
C
C       WRITE(*,*) RCSUM
C
C Derive range for scaling factor k
C
      SCMIN = HALF / SCMIN
      SCMAX = SCMIN + M / RCSUM
C
C
C Derive linear predictor, sum of squares and sum of weights
C
      WTSUM = ZERO
      YSS = ZERO
      DO 30 I = 1, L
        IF ( WT(I) .EQ. ZERO ) GO TO 30
        T = ZERO
        DO 20 J = 1, N
          T = T + RC(J) * X(J,I)
20      CONTINUE
        Y(I) = T
        WTSUM = WTSUM + WT(I)
        YSS = YSS + T * T * WT(I)
```


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```
30     CONTINUE
      IF ( WTSUM .LE. ZERO .OR. YSS .LE. ZERO ) RETURN
      NSC = 0
      DO 40 I = 1, M
        WORK(1,I) = ZERO
40     CONTINUE
C
C For each coefficient in turn...
C
      DO 130  I = 1, N
        RCT = ABS(  RC(I) )
        IF ( RCT .EQ. ZERO ) GO TO 130
C
C     ....Derive scaling factors at integer boudaries...
C
       JMIN = NINT( RCT * SCMIN + EPS )
       JMAX = NINT( RCT * SCMAX + EPS )
       DO 120 J = JMIN, JMAX
         SC = ( J - HALF ) / RCT
         IF ( SC .LT. SCMIN .OR. SC .GT. SCMAX ) GO TO 120
C
C ...Derive sum of squares and sum of products for
C       each scaling factor
C
         RCSS = ZERO
         RCSP = ZERO
         DO 50  K = 1, N
          WORK2(K) = NINT( RC(K) * SC + SIGN( EPS, RC(K)))
50        CONTINUE
C
         DO 70 K = 1, L
           IF ( WT(K) .EQ. ZERO ) GO TO 70
           T = ZERO
           DO 60 KK = 1, N
             T = T + WORK2(KK) * X(KK, K)
60           CONTINUE
           RCSS = RCSS + T * T * WT(K)
           RCSP = RCSP + T * Y(K) * WT(K)
 70       CONTINUE
C
C      Sort by scaling factor
C
         NRC = 0
 80       NRC = NRC + 1
         IF ( NRC .GT. M) GO TO 120
         IF ( ABS( SC - WORK(1,NRC) ) .LT. SC * EPS ) GO TO 120
         IF ( NRC .LE. NSC .AND. SC .GT. WORK(1,NRC)) GO TO 80
         IF ( NSC .LT. M)  NSC = NSC + 1
         IF ( NRC .EQ. NSC ) GO TO 110
         DO 100 K = NSC - 1, NRC, -1
           DO 90 KK = 1, 3
```


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```
           WORK(KK,K+1) = WORK(KK,K)
90         CONTINUE
100       CONTINUE
110       WORK(1, NRC) = SC
         WORK(2, NRC) = RCSS
         WORK(3, NRC) = RCSP
120      CONTINUE
130     CONTINUE
C
C Identify optimal values for scaling factor
C
      IF (NSC .LE. 1 ) RETURN
        SDP = BIG
      DO 150 K = 1, NSC - 1
        RCSS = WORK(2,K)
        RCSP = WORK(3,K)
        IF ( RCSP .EQ. ZERO ) RETURN
C
C                  Adjust scaling factor and derive residual sum of squares
C
        SC = RCSS / RCSP
        IF ( SC .LT. WORK(1,K) ) THEN
          SC = WORK(1,K)
        ELSE IF ( SC .GT. WORK(1,K+1) ) THEN
          SC = WORK(1,K+1)
        END IF
        SD = YSS - 2 * RCSP / SC + RCSS / ( SC * SC )
        IF ( SD .LT. EPS * YSS ) SD = ZERO
        IF ( K .EQ. 1 .OR. SDP .GT. SD .OR. .NOT. OK
   *      .OR. ( NS .GT. 0 .AND. SDP .GE. SDPP ) )  GO TO 140
        NS = NS + 1
        WORK(1,NS) = SCP
        WORK(2,NS) = SQRT( SDP / WTSUM)
        SDPP = SDP
140       OK = (SD .LT. SDP)
        SDP = SD
        SCP = SC
150     CONTINUE
C
C
      RETURN
      END
C
      SUBROUTINE RCINT2(N, RC, INT, SCALE)
C
C
C
      INTEGER N
C
      IMPLICIT DOUBLE PRECISION (A-H, O-Z)
      DIMENSION RC(N), INT(N)
```


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```
      DATA EPS / 1D-8 /
C
C
C
      DO 10 I = 1, N
        INT(I) = NINT( RC(I) * 6.5 + SIGN( EPS, RC(I) ) )
10    CONTINUE
C
      RETURN
      END
```


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Appendix VI

RELEVANT PUBLICATIONS

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