EPIDEMIOLOGY OF MUAY THAI FIGHT-RELATED INJURIES

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Submitted to the Graduate Faculty of

Epidemiology

Graduate School of Public Health in partial fulfillment

of the requirements for the degree of

Doctor of Philosophy

University of Pittsburgh

2014

UNIVERSITY OF PITTSBURGH

GRADUATE SCHOOL OF PUBLIC HEALTH

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ABSTRACT

Combat sports are generally considered more dangerous and risky compared to other athletic activities, as scoring is inextricably linked to inflicting damage on an opponent. This fundamentally unique intent, to injure an adversary in a contest is replete with injury risks from physical exposures. One combat sport increasingly popular among US youth, known as Muay Thai, yields scant epidemiologic study on fighter injuries.

To develop a surveillance system to provide magnitude and scope of injury outcomes in order to frame the public health significance.

Three surveillance approaches were utilized to identify eligible participants to complete a web survey regarding Muay Thai fight-related injuries. The target population yielded a convenience sample of 195 fighters participating in sanctioned fights across North America and the UK. Regression analyses were conducted to determine whether the injury outcome was related to additional factors such as experience, protection and pre-existing injury.

Depending on the approach, contact rates ranged from 83.3-100%; cooperation rates ranging from 44-80%; response rates ranged from 30-60% and 20-55%. Fighters were aged 18 to 47 years old (median 26); predominantly male (85.9%); and white (72.3%). Respondents were professional (n=96, 49.2%) and amateur (n=99, 50.8%) Fighters reported a range of fight experience from 1-111 total fights, with a mean of 15.83. Of the 195 respondents, 108 (55.4%) reported sustaining an injury during the fight. The primary body region that was injured were the extremities (58%). The primary cause or mechanism of the fight injuries was due to being “struck by” the opponent in more than 2/3 of the incidents. Nearly 2/3 (66.7%) of all injured fighters reported that the injury did not interfere with the completion of the fight and was not a factor in the bout outcome (i.e., win, loss, draw). Nearly 25% reported they missed no training time as a result of the injury incurred during the fight. Subsequent regression models yielded several individual level variables of interest relative to the injury outcome. These included fighter status, weight, age, equipment and previous injury.

The majority of the injuries incurred by fighters were mild in severity to the extremities, as a result of being struck by or striking the opponent. Lighter, younger, and more experienced fighters were at increased odds for injury within this sample.

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PREFACE

I would like to that the members of my dissertation committee (Drs. Thomas Songer, Anthony Fabio, Maria Brooks and Jeffrey Coben) for their collective tutelage and guidance. You taught me immeasurable academic lessons during the process. My sincere appreciation to Tom, for being there from the start and helping me push beyond the obstacles and share in this accomplishment.

I dedicate this work and give special love and thanks to my wife and best friend, Dr. Elsa S. Strotmeyer. Thank you for being there for me throughout the entire doctorate program, for your patience, support and endurance. Thank you to my children, Kalina and Stellan for being my cheerleaders and sharing in the joy of this accomplishment. You helped fuel my ambition to graduate and tackle new endeavors. A special feeling of gratitude to my loving parents, Kathaleen and Stephen, whose words of encouragement and push for tenacity ring in my ears every day. Thank you to my mother and father-in-law, Janet and Lawrence Siulc, for their support over the years and their enthusiasm as I neared my goal. Thank you to my gram, Mary Lou Buckley for your undying support and excitement.

I also dedicate this dissertation to my many friends and colleagues from the sport of Muay Thai, especially my Pittsburgh Muay Thai family, who supported me throughout the process. I will always appreciate all they have done, especially when preparing for my defense. To all of the fighters that participated, I thank you for your time assisting with my research, and laud your efforts every time you enter the ring.

1.0 INTRODUCTION

Injuries are a significant public health issue in the United States and the World, accounting for large numbers of death, disability and cost. The Centers for Disease Control and Prevention reported that injury ranked as the 5th leading cause of death in the United States (n=118,043) in 2010. This resulted in an age-adjusted death rate of 38.2/100,000. Injuries are the the leading cause of premature death measured in years of productive life lost (YPLL) before the age of 65 and all causes of injury represented nearly 30% of the total prematurity as depicted in Table 1 below. Thus, the prevention and control of injury-related mortality, morbidity and disability has become important both nationally and globally.

Table 1. Year of Potential Life Lost (YPLL) Before Age...

Years of Potential Life Lost (YPLL) Before Age 65, All Races, Both Sexes All Deaths (2010 United States)		
Cause of Death	**YPLL**	**Percent**
All Causes	11,043,870	100.0%
Unintentional Injury	**2,083,297**	**18.9%**
Malignant Neoplasms	1,843,612	16.7%
Heart Disease	1,348,874	12.2%
Perinatal Period	786,472	7.1%

Table 1 Continued

Suicide	**764,776**	**6.9%**
Homicide	**522,701**	**4.7%**
Congenital Anomalies	439,731	4.0%
Liver Disease	263,317	2.4%
Cerebrovascular	230,587	2.1%
Diabetes Mellitus	216,229	2.0%
All Others	2,544,274	23.0%

Data Source: National Center for Health Statistics (NCHS) Vital Statistics System

Injury is the unintentional or intentional damage to the body resulting from acute exposure to thermal, mechanical, electrical, or chemical energy or from the absence of such essentials as heat or oxygen.

The Centers for Disease Control and Prevention (CDC) stated the risk of injury is so great that the majority of people sustain a significant injury at some time during their lives (CDC, 2010). Many believe that injuries and the subsequent human damage that happens occur randomly, however, this belief implies that injuries are unpreventable. Alternative opinions adopted by most injury professionals today consider that many injuries are not “accidents,” or uncontrollable acts of chance; rather, most injuries are predictable and preventable (Houk, 1987). This counter argument and awareness is largely attributed to the efforts of the CDC over the past 25 years.

The National Center for Injury Prevention and Control (NCIPC) at the CDC collects and reports national statistics on injuries in order to frame the magnitude and public health burden of injury. The following statistics compiled by the NCIPC are presented to highlight the frequency, distribution and impact of injury in America (Figure 1).

• Injuries are the leading cause of death for people ages 1–44.[1]
• More than 180,000 people die from injuries each year—1 person every 3 minutes.[1]
• Injuries cost more than $406 billion annually in medical care and lost productivity.[3]
• More than 2.8 million people hospitalized with injury each year.[2]
• Violence and injuries cost more than $406 billion in medical care and lost productivity each year[2]
• More than 31 million people treated in Emergency Department for injury each year.[2]
• Treatment of injuries and their long-term effects account for 12% of medical care spending, totaling $69 billion (in 1993 dollars) (Institute of Medicine, 1999).

1. NCIPC: Web-based Injury Statistics Query and Reporting System (WISQARS)http://www.cdc.gov/injury/wisqars.

2. NCHS. National hospital discharge survey: 2007 summary. National health statistics reports, no. 29. Atlanta, GA; 2010.

3. Finkelstein EA, Corso PS, Miller TR, Associates. Incidence and economic burden of injuries in the United States. New York, NY: Oxford University Press; 2006.

Figure 1. Injury Burden in America

Table 2. Leading Causes and Total 5-Year Incidence of Deaths by Age Group, United States, 2004-2008

	Age Groups					
Rank	<1	1 - 4	5 - 9	10 - 14	15-19	20-24
1	Congenital Anomalies 28,416	Unintentional Injury 7,972	Unintentional Injury 5,042	Unintentional Injury 6,350	Unintentional Injury 32,134	Unintentional Injury 45,283
2	Short Gestation 23,808	Congenital Anomalies 2,673	Malignant Neoplasms 2,407	Malignant Neoplasms 2,368	Homicide 10,618	Homicide 16,476
3	SIDS 11,605	Homicide 1,937	Congenital Anomalies 949	Suicide 1,164	Suicide 7,953	Suicide 13,202
4	Maternal Pregnancy Comp. 8,708	Malignant Neoplasms 1,911	Homicide 638	Homicide 1,088	Malignant Neoplasms 3,495	Malignant Neoplasms 4,891
5	Unintentional Injury 5,882	Heart Disease 858	Heart Disease 486	Congenital Anomalies 885	Heart Disease 1,824	Heart Disease 3,558

Produced by WISQARS

Thus, injury remains a serious public health problem because it accounts for significant premature death, disability, and burdens the healthcare system. Table 2 illustrates the burden with respect to mortality. Because injuries are preventable and avoidable outcomes, the public health approach traditionally applied to infectious or chronic diseases has recently been applied within the injury research field. Researchers are scientifically and systematically describing the injury problem through surveillance, studying factors that increase or decrease injury risk, designing and evaluating intervention strategies that target these risk factors, and taking steps to ensure that proven strategies are implemented in communities nationwide (Figure 2).

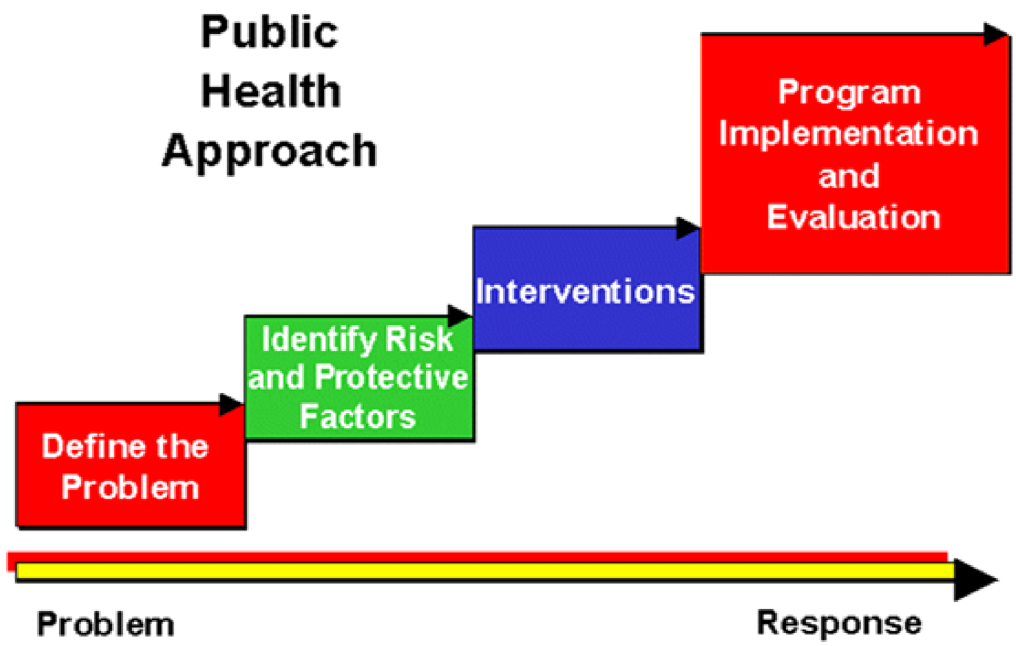


Figure 2. Public Health Approach

A significant proportion of injury occurs within sports and recreational activities. As physical activity continues to be promoted as part of a healthy lifestyle, sports and recreational injuries have become an important public health issue. Among nonfatal injuries, more sports and recreational injuries are treated in hospital emergency departments than any other type of unintentional injury.[1] The National Health Interview Survey (NHIS) reported an annual estimate that seven million Americans received medical attention for sports-related injuries (25.9 injury episodes per 1000 population) 1997-1999. The CPSC's National Electronic Injury Surveillance System All Injury Program (NEISS-AIP) approximates that 4.3 million sports and recreational injuries were treated in hospital emergency departments annually. That represents 15.7% of all non-fatal injuries. Both the NHIS and NEISS reported basketball as most frequently mentioned sports and recreational activity in which the injury episode occurred. Further review of the NHIS system revealed strains and sprains accounted for 31% of injury episodes. An estimated 1.1 million sports and recreational episode related injuries involve the head or neck region, of which 17% were internal head injuries. The most common mechanisms of injury were struck by/against (34%), fall (28%), and overexertion (13%).

The incidence of sports and recreational injuries remains a significant source of morbidity among particularly the younger age groups, and those injuries captured through the major surveillance system are predictably under reporting the full magnitude of the problem. In order to achieve the lofty goals of controlling and reducing sports and recreational injury, a significant amount of research is required to reduce injuries among the high risk sectors. As we continue to promote health and physical activity across a broad array of various organized sports to recreational activities, the potential to further injury efforts remains open. Coordination of efforts is needed to properly develop standardized instruments that capture exposure information and injury outcomes among at the population level. That data can be used for computing rates,

[1] 1. Prevention CDC. Nonfatal sports- and recreation-related injuries treated in emergency departments - United States, July 2000 - June 2001. CDC Morbidity and Mortality Weekly Report 2002;51:736-740.

comparing risk, assessing priorities so that well-constructed prevention efforts are rooted in science, extend beyond anecdote.

One emerging sport in the USA involves combat sports. The high profile of modern Mixed Martial Arts (MMA) promotions such as Ultimate Fighting Championship (UFC) has fostered an accelerated development of the sport. UFC commentator Joe Rogan claimed that martial arts evolved more in the ten years following 1993 than in the preceding 700 years combined during a Pay-per-view broadcast of UFC 40 (Liddell versus Sobral). The explosion into the mainstream of MMA as a spectator sport has impacted participation in a veritable mix of martial arts. From striking sports like boxing and kickboxing to grappling sports like Brazilian Jiu-Jitsu and wrestling, the combat sports have seen an increase in participation over the past decade whether for fitness, fun or competition. According to data from New York City-based research firm Simmons Market Research, 18.1 million Americans participated in some form of martial art at least once in the past year with approximately 30,000 martial arts schools in the United States. This included 9.4 million adults, 5.5 million teenagers and 3.2 million children. Five percent of adults participated in the martial arts last year at least once, and 28% say they do martial arts "every chance they get". This group splits fairly evenly between men and women (52% to 48%). When reporting age, the breakdown is as follows: 18-34 63%; 35-49 25%; 50 or older 11%.

This dissertation will focus on examining the feasibility of establishing a surveillance system for a single combat sport, Muay Thai. We aim to quantitatively assess feasibility of an injury surveillance system by calculating response, cooperation, contact and refusal rates. Additionally, the project will assess the timing window for maximizing contact and participation in the surveillance system. Beyond those primary aims, we plan to describe the frequency and severity of Muay Thai fight-related injuries among the collected sample of professional and amateur fighters, and study the factors related to Muay Thai fighting injuries. Gaining more insight into the nature and frequency of injury in this combat sport provides part of the overall sports injury picture, within the larger burden of injury as a public health issue. Generating this information is a critical first step toward the broader goal of improving the health and safety of Muay Thai fighters engaged in competition.

In order to accomplish this task, we will begin by briefly highlighting major literature on the epidemiology of injury. This will define injury, describe key surveillance systems, discuss methodologies, and discuss the role of epidemiology in the evaluation of injuries. A more detailed literature review specific to the epidemiology of combat sports injury will present descriptive information regarding the frequency, nature and determinants found in previous studies. Further review will identify risk factors of injury in combative sport identified in analytic studies, and those which specifically address correlates which may explain risks or protective effects. The assimilation of this research will be used to explain the rationale for the current study and how this proposal seeks to identify gaps in present scientific knowledge, hoping to augment and advance in those literature-based resources. The research hypotheses will frame specific questions to be answered through analyses conducted on the collected data, presented and discussed using the traditional formula for presenting scientific investigations.

2.0 INJURY DEFINITION

2.0.1 Introduction

The field of injury research and control has made many advances over the past ½ century. Important considerations when reflecting on that process include: 1) the development and refinement of operational injury definitions; 2) the application of epidemiologic research methodologies to study injury; 3) the adaptation or creation of surveillance systems to collect injury data; and 4) the implementation of both descriptive and analytic research designs aimed at enhancing our knowledge of the frequency, nature and determinants of injury.

2.0.2 Defining Injury

Perhaps one of the first discussions regarding injury research is to define an injury. In general, injury is defined as the unintentional or intentional damage to the body resulting from acute exposure to thermal, mechanical, electrical, or chemical energy or from the absence of such essentials as heat or oxygen. When the level of energy exceeds the body's ability to absorb it, a physiologic threshold is exceeded, resulting in an injury. How we get to this standard is an interesting story.

Historically, injury has been viewed from many perspectives. For example, there has been a shift in emphasis from the common term "accident" to the less fatalistic term "unintentional injury" in the last 50 years. The view of injuries as an "accident" was thought to be an amorphorous emphasis since it implied that accidents were fatalistic events (i.e., in the wrong place, at the wrong time) and even referred to events where no injuries occur. As Robertson stated, “accidents were unintended events that interfered with one’s daily pursuits” (Robertson, 1992). These random and arbitrary events could often lead to an injury, and were thought to be more of an “act of God” rather than events attributable to human error.

The evolution in perspective from accident to unintentional injury can be traced to the thinking of recent injury research scientific pioneers. Ross McFarland was one of the first researchers to formally define what constituted an accident. He attempted to construct a definition since the previous studies in the field had no working standard, and imprecise terminology was a major limitation for systematic research (McFarland, 1954). McFarland explored a promising proposal to serve as a standard for research in the accident field. Building off of research conducted by Arbous, he submitted this case definition as the basis for future research:

> “In a chain of events, each of which is planned to controlled there occurs an unplanned event, which, being the result of some nonadjustive act on the part of the individual (variously caused) may, or may not result in injury. This is an accident.” (Arbous, 1951)

In order to integrate the various types of research being conducted within the accident field, McFarland saw the necessity to develop and promote a universal definition as the primary step. Using a standard definition allows researchers to direct attention to injury and noninjury events, and to further categorize and classify accident data. This is imperative when assessing the comparability of research data. Previous research studies had used varying injury definitions that were not comparable. This discontinuity resulted in conflicting results and general confusion regarding the nature of injuries.

Once a level of precision was applied to the definition of an accident, the etiological nature associated with an injury outcome could be explored. The epidemiological method represents a scientific method to investigate the frequency, distribution and determinants of a disease or other health-related outcome on a population. Traditionally, a theoretical model has been applied to better understand how disease or injury increased or decreased in the community. The core concepts of this model are known as the epidemiologic triad (Figure 3).

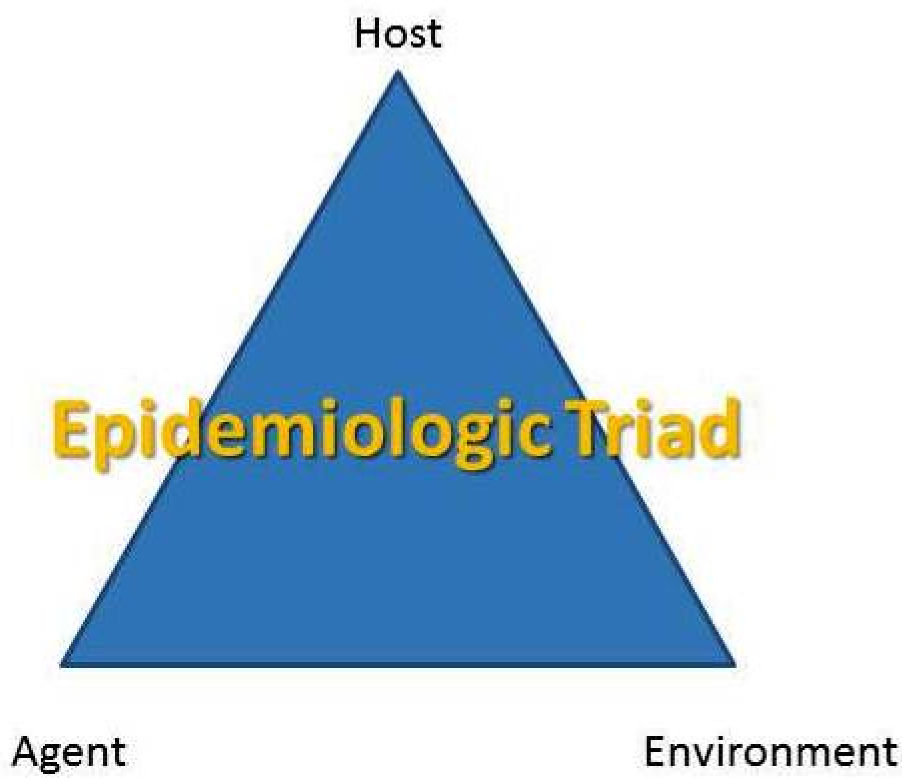


Figure 3. Epidemiologic Triad

The success of the epidemiologic approach to the control of many infectious diseases led to its use in injury control, although injury epidemiology developed much later as a distinct discipline. As John Gordon noted, “when the prevalence and incidence of accidental injuries have been analyzed in a standard epidemiologic manner, it has been shown that accident distributions, like disease, show characteristic variations” (Gordon, 1949). In actuality, injuries affect subpopulations differently – there are different rates, agents and circumstances dependent on factors such as age, race and gender. When the specific variables are teased out, the etiology of accidental injury became evident, in that injuries could be viewed as having the characteristics of an epidemic. McFarland stated that “the epidemiologic study of accidents may be considered analogous to the study of diseases where the agents are known, but the causative associations and interrelationships in the host-agent-environment complex are not known” (McFarland, 1961). He commented that the study of accidents really involved the interrelationships between the host, agent and environment, and these factors interacted in such a manner as to produce an accident.

While Gordon conceptualized the multifactorial nature of injuries, other early researchers began to develop the elements of the triad. Host (human) factors that affect the frequency and types of accidental injuries include: age, gender, race/ethnicity, marital status, socioeconomic factors, psychological factors and physical/mental conditions. Environmental factors include those identified by Iskrant and Joliet as factors involving time and place, such as home, farm, industrial premise, place of sport or recreation, resident institution, geography and weather (Iskrant, 1968).

Environmental factors consist of both physical and psychosocial elements. Since they are not merely limited to time and place, there is a plethora of environmental circumstances associated with different types of injuries. In a general sense, researchers have attempted to categorize the environmental factors broadly, rather than amassing an exhaustive list of specific factors. To paraphrase Barss’s observations, the environment can be substantially affected by socioeconomic status, residential location, modern development, and climate. Furthermore, the environment is affected by time, in that hazards may become more or less injurious during daylight versus nighttime, on weekends versus weekdays (Barss, 1998).

James Gibson, a psychologist by training, was credited with specifying that energy transfer was an important causal agent in the injury after stating that "Injuries to a living organism can be produced only by some energy interchange" (Gibson, 1961). Rockett credited Gibson with “enabling a great etiologic leap in injury research” (Rockett, 1998). By exploring the etiology, or more importantly, the energy transfer to the human being, prevention and control efforts could be applied. Too much or too little energy transfer would harm the human body. In other words, energy transfers falling below or exceeding the injury threshold of what the human body can tolerate would cause injury. Six forms of energy transfer were identified:

1. Mechanical
2. Chemical
3. Thermal
4. Radiation
5. Electrical
6. Asphyxiation.

Injuries were then classified as reflections of abnormal energy transfer. In the post-Gibson era of injury research, the agent of injury predominantly involves the abnormal transfer of energy to the human being in such a way as to cause damage to cells/organs/tissues or to deprive the body of essential elements such as oxygen. Further refinements in this notion of abnormal energy transfer were developed within trauma settings to characterize the injury as penetrating, non-penetrating, compressions, burns and suffocations.

Although Gibson was the first person to correctly identify the agent in accidental injuries as energy transfer, many of the epidemiologist’s earlier works focused on types of accidents or accidental circumstances. For instance, types of accidents involved motor vehicle, falls, machinery-related, firearms, drownings, poisonings, et cetera.

The interaction of different combinations of the host-agent-environment may have additive or even multiplicative effects on the probability of injury. The synergy between personal risk factors and environment may be one of the most important determinants of injury, and offers a serious challenge in terms of reducing morbidity and mortality. Achieving a significant reduction in any type of injury requires a multi-pronged approach which addresses all elements of the epidemiologic triad.

It is a combination of these factors (i.e., host, agent, environment) that can often be identified when assessing risk. For example, urban children playing at dusk near crowded streets are substantially more at risk for a pedestrian-related injury than suburban children playing at the same time in a residential backyard. This example serves to illustrate that differences in unintentional injuries reflect differences in exposure to environmental hazards. Since there is such a widespread variation in exposures, it becomes difficult to quantify these hazards without maintaining a general vantage point. The relative importance of specific mechanisms of injury may vary widely from one location to the next simply because of the nature of the physical environment. To emphasize this point further, consider that drownings and submersions would virtually have no impact in arid, desert-like regions, but would have a much greater impact on areas that are quite inundated with lakes, rivers, streams, etc. In a similar sense, falls related to snow and ice would be a significant change in the environment in some temperate regions of the world, but never affect the tropical areas.

2.0.3 The Role of Haddon

The establishment of energy transfer as the injury agent led to the development of control and prevention strategies. It was soon discovered, however, that the variety of energy sources involved in injury, and differences in the distribution of injury within the population, mitigated against a single control strategy. William Haddon, Jr. advanced this thinking dramatically. In 1964 Haddon published his statement of the energy transfer theory:

> "Accidents, at least those of concern to the medical profession, are defined in effect by the unexpected occurrence of injury. The first of these comprises all injuries caused by interference with normal whole body or local energy exchange. At the whole body level, examples of injuries due to such interference with normal energy exchange include the results of suffocation by mechanical or chemical means for example, by drowning, strangulation, carbon monoxide inhalation and cyanide poisoning. Foremost are injuries due to the delivery of **mechanical** energy. The impacts of moving objects such as bullets, hypodermic needles, knives, and falling objects and those produced when a moving body collides with relatively stationary structures, as in falls, plane crashes, and auto crashes illustrate this group. The energy transferred injuriously may also be **thermal**, as in the case of first, second, and third degree burns; electrical, as in electrocution; or, it may be ionizing **radiation**. Finally, **chemical** energy may also be transferred in excess of body thresholds, and this group of injuries includes all those due to plant and animal toxins, and to inorganic and organic compounds. Viewed in this light, the fundamental problem in the prevention of injury is the prevention of such abnormal energy exchanges, and research in accident causation and prevention can and must be analyzed in similar terms" (Haddon, 1964).

Later, Haddon published another groundbreaking observation which presented a series of priority ranked countermeasures aimed towards prevention, control or reduction of the frequency of injuries. He stated that "in its most common form, it states that because drivers cause most accidents, programs correspondingly must be concerned with drivers. In the real world, there is no basis for making this assumption" (Haddon, 1973). Table 3 shows Haddon's strategies for injury prevention with an applied example. It illustrates that many strategies exist to reduce injuries. The one chosen will depend on a combination of practicality and effectiveness, and oftentimes, several of the countermeasures can be selected for a multifaceted approach. For example, strategy #1 (Preventing the Hazard) would generally be the most effective method of injury prevention, but it is often impractical. If this is the case, simply move down the list to find the measures that may be effective given the circumstances surrounding the type of injury specified.

Table 3. Haddon Matrix Application

Strategies for Injury Prevention	Examples
Prevent the creation of the hazard in the first place.	Don't build all terrain vehicles (ATVs). (Obviously, this does not seem practical. The message in this strategy is to consider what hazards might be created when you design or start something new.)
Reduce the amount of the hazard created.	Package medications in smaller amounts.
Prevent the release of a hazard that already exists.	Improve the braking capability of a car.
Modify the rate or spatial distribution of the hazard from its source.	Build cars with airbags.
Separate in time or space the hazard from that which is to be protected.	Build pedestrian walkways.
Separate the hazard and what is to be protected by a material barrier.	Separate drivers from a drop-off in the road by building guard rails.
Modify relevant basic qualities of the hazard.	Build cribs with slats too narrow to strangle a child.
Make what is to be protected more resistant to damage from the hazard.	Physical conditioning.
Move rapidly to detect and evaluate damage that has occurred and counter its continuation and extension.	Train people in First Aid.
Stabilize, repair, and rehabilitate the damaged object.	Develop a regional trauma system.

Source: Injury Prevention: A Guide for Aboriginal Communities. Injury Prevention Centre, Edmonton, Alberta, 1995.

Haddon defined ten distinct prevention strategies and developed a matrix to provide a relevant example. Now recognized as the father of injury control, Haddon was the former director of the National Highway Traffic Safety Association (NHTSA). His early work developed significant programs within the injury field with a primary focus on motor vehicle-related injuries (Haddon, 1959). He advanced the science of injury control, and was one of the first researchers to elaborate on energy transfer as the injury agent, furthering Gibson's achievements.

He did this by developing a universal matrix which examines the phases of a motor vehicle crash sequence temporally and links these to the fundamental epidemiologic principles that describe injury causation. This basic research application began to highlight injuries as a public health problem by looking for the causal and contributing factors versus simply relying on a description of who gets injured. The Haddon Matrix (Table 4) integrated the temporal phases of a motor vehicle crash (i.e., factors before, during and after the crash) with the epidemiologic triad, which he called the human (host), vehicle (agent) and environmental components. He argued that in order to effectively address injuries sustained from motor vehicle crashes, this continuum needed to be fully understood by the investigator in order to identify major modifiable factors.

Table 4. Traditional Haddon Matrix

Traditional Haddon Matrix, Motor Vehicle Injury				
		Epidemiological Dimension		
Event Dimension		Human	Vehicle	Environment
	PRE	Intoxicated driver	Speeding	Night, rainy weather
	CRASH	Not wearing seatbelt	Vehicle not equipped with supplemental restraints (airbags)	Utility pole too close to roadside
	POST	Elderly driver		Slow emergency response in rural area

Energy transfer underlies the matrix as the agent, producing injury if present in a susceptible host. The three phases of the event dimension were conceived to represent the build-up of energy in the pre-crash or pre-event phase, the transfer of energy in the crash phase, and the effect of the energy in the post-crash phase on the person, vehicle on environment. For example, the kinetic energy generated while driving a car is transferred to the human driver as mechanical energy transfer when impacting a stationary object such as a tree or utility pole, thereby causing injury to the person, damage to the vehicle and the surrounding objects. The monumental nature of this model is universally accepted as a teaching instrument for all novice injury researchers, and is applied to all injury mechanisms, not only motor vehicle crashes.

Other researchers, including Runyan and Fowler, have recently explored and expanded on the Haddon Matrix (Table 5), adding new dimensions to reflect the sociocultural and socioeconomic influences within the environmental dimension (Runyan, 1998; Fowler, 1999). The example given demonstrates the applicability to pedestrian injury with the 4th dimension highlighted. Prior to the event, low law enforcement of speeding would influence the injury outcome, followed by obeying speed limits and finally the provision of care within the community. While the revised matrix does identify additional modifiable risks for injury, the original Haddon matrix remains a cornerstone upon which the modern injury research field was constructed.

Table 5. Revised Haddon Matrix

Revised Haddon Matrix, Pedestrian Injury Application					
		Epidemiological Dimension			
Event Dimension		Human Factors	Agent or Vehicle	Physical Environment	Sociocultural Environment
	PRE	Intoxicated pedestrian, Age	Speeding vehicle, Braking and maneuverability	Intersection with poor lighting	Low rate of enforcement
	CRASH	Osteoporosis in elderly pedestrian	Car front-end profile	Road surface characteristics	Speed limits
	POST	Elderly pedestrian, Preexisting medical conditions	Crash investigation with vehicle inspection	Proximity to trauma facility	Regionalized trauma care system

2.1 INJURY SURVEILLANCE

Several advances in the injury field have come about with the development of injury surveillance systems. Both governmental and private agencies maintain data systems that collect data on injuries. These systems are used to measure trends, detect clusters, and identify risk factors related to injury. Collectively, these are called injury surveillance systems, and the primary objectives for these systems are to generate information to be used both for determining the need for injury prevention activities and to assess the effectiveness of injury programs.

It is important to draw a distinction between two major categories of injury – unintentional and intentional. Unintentional injuries have traditionally been labeled 'accidents', or random, uncontrollable acts of fate, although today they are largely viewed as being preventable. Intentional injuries deal with purposeful or deliberate intent to injure oneself or another person. This distinction is depicted in Figure 4.

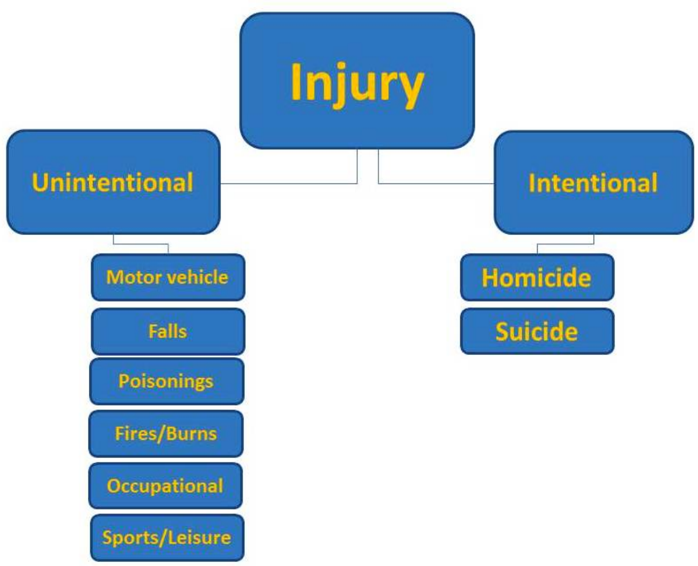


Figure 4. Injury Categorical Flowchart

There are several general surveillance systems that exist to monitor injuries. These include systems based upon case series of reports in the media, registries, population-based data, surveys and internet sources. These systems provide information on injury circumstances, setting, and demographics at the national, state and local levels. This broad array of data is useful for understanding the extent and mechanisms for injuries in particular geographic areas, and includes public health data, medical data, and data on behaviors associated with injury (Posner, 1996). Surveillance systems for injuries are largely based on reporting unintentional events. Surveillance for intentional injuries has evolved as a more recent priority among public health practitioners. Most surveillance for intentional injury outcomes emanates from traditional criminal justice data or recent modifications to the unintentional injury data systems.

The following section describes the major sources of data on injuries in the US, and evaluates their utility and limitations for epidemiologic research and practice. A description of each national data system follows. While these systems use different data sources and a variety of methods for case identification, measurement, analysis and reporting, they collectively provide a broad assembly of useful information on injuries. Table 6 provides an overview of the attributes of the major, national surveillance systems.

Table 6. Summary of Ongoing National Injury Surveillance System Attributes

Surveillance System	Type of Injury Data	Injury Case Identification	Misclassification	Sources of Injury Data
National Vital Statistics System (NVSS)	Mortality	Coroner or Medical Examiner affirmation	False positives	Vital Statistics Record
National Ambulatory Medical Care Survey (NAMCS)	Morbidity	ICD-09 coding	Miscoding	Physician Record

Table 6 Continued

National Hospital Discharge Survey (NHDS)	Morbidity, Mortality	ICD-09 coding	Miscoding	Hospital Discharge Record
National Hospital Care Survey (NHCS)	Morbidity, Mortalitiy	ICD indicator	Miscoding	Inpatient hospital discharge (HDD), emergency department (ED), outpatient OPD), hospital-based ambulatory surgery (ASL), freestanding ambulatory surgery center (ASC) & (NHAMCS)
National Hospital Ambulatory Medical Care Survey (NHAMCS)	Morbidity	ICD-09 coding	Miscoding	ED Record, Outpatient Record
National Health Interview Survey (NHIS)	Morbidity, Incidence, Prevalence	Self-report	Subject to personal, interviewer & recall bias	Telephone or In-person Interview
National Electronic Injury Surveillance System (NEISS & NEISS-AIP)	Morbidity, Mortality, Incidence	Diagnosis code	Miscoding	ED Record
National Automotive Sampling System (NASS-GES)	Morbidity, Mortality	Police investigation	Potential undercount since only collects Police reported crashes only	Police Report
Fatality Analysis Reporting System (FARS)	Mortality, Risk Factors, Incidence, Prevalence	Police investigated MV fatalities occurring on roadways	Potential undercount since only collect fatalities occurring within 30 days of incident	EMS Record, ED Record, Medical Examiner, Police Report, Vital Statistics
Census for Fatal	Mortality, Risk	Telephone or in-person Interview	Insufficient detail may preclude	Physician Record, EMS Record, ED Record, Trauma Registry,

Table 6 Continued

Occupational Injury (CFOI)	Factors, Incidence		designation as "work-related"	Specialized Injury Registry, Worker's Compensation, Insurance Provider
Survey of Occupational Injuries and Illnesses (SOII)	Morbidity, Prevalence	Self-report	Insufficient detail may preclude designation as "work-related"	Employer/Employee Questionnaire
National Traumatic Occupational Fatality Surveillance System (NTOF)	Mortality, Incidence, Prevalence	ICD-09 coding	Miscoding, Failure to designate work-relatedness	Vital Statistics (Death Certificate)
Behavioral Risk Factor Surveillance System (BRFSS)	Risk Factors	Self-report	Subject to personal bias, interviewer bias, recall bias	Telephone Interview
National Crime Victimization Survey (NCVS)	Morbidity, Incidence, Risk Factors	Personal report	Subject to personal bias, interviewer bias, recall bias	Telephone or In-person Interview
National Violent Death Reporting System (NVDRS)	Mortality	ICD-10	Misclassification on suicide surveillance	Death certificates, coroner/medical examiner reports, police reports & crime laboratories
National Intimate Partner & Sexual Violence Survey (NISVS)	Prevalence estimates	Physical violence by intimate partner	Missclassification of minor to severe forms of physical violence	Random digit dial telephone survey (dual sampling frame)

2.1.1 National Injury Surveillance Systems

- *National Vital Statistics System (NVSS) - Mortality Data*

Much of what we know regarding injury epidemiology has been generated from the mortality data of the NVSS. The National Center for Health Statistics (NCHS) routinely collects, analyzes and publishes mortality data obtained from death certificates throughout the US. This system provides data procured from death certificates including the underlying and contributing causes of death; demographics of the decedent; place of occurrence; place of residence and educational attainment. In general, a physician, coroner or medical examiner completes the medical part of the record and sends the rest to the funeral director to add demographic information before filing the certificate with the state's vital statistics office. NCHS purchases this death certificate information either in electronic or paper form from every state annually. This data is entered into the NVSS system and eventually converted into rates, numbers, gender and geographic detail for all deaths in the US.

One of the most significant attributes of this surveillance system was the use of International Classification of Disease (ICD) code classifications to identify injury events from 1981-1998. In ICD-9, injuries are identified on the basis of both a diagnosis code (N-code) and external cause of injury (E-code) code.

> *N-codes:*
> These are diagnostic groupings related to the nature of the illness or injury or what happened to the body. They are numbered 1-999, with an injury-specific range from 800-995. The nature alone does not provide information regarding intent, but it does identify injury events or outcomes.

> *E-codes:*
> These provide a system for coding the cause of injury, such as environmental events, circumstances and conditions that cause an injury. These E-codes,

numbered E800-E999, are used for both unintentional and intentional injuries and can create a snapshot of the specific circumstances for an injury.

Beginning with data year 1999, a new ICD system was implemented for mortality data, ICD-10. In the updated International Classification of Diseases 10th Revision, conditions have been grouped in a way that was felt to be most suitable for general epidemiological purposes and the evaluation of health care. From an injury perspective, ICD-10 is much more comprehensive than ICD-9. The number of injury categories available for the classification is significantly enlarged, sometimes further detailed, and sometimes less detailed (see Table 7 next page). The CDC Web site comments on how ICD-10-CM differs from ICD-9:

> Notable improvements in the content and format include: the addition of information relevant to ambulatory and managed care encounters; expanded injury codes; the creation of combination diagnosis and or symptoms codes to reduce the number of codes needed to fully describe a condition; the addition of a sixth character; incorporation of common 4th and 5th digit sub-classifications; laterality; and greater specificity in N-code assignment. (CDC, 2000).

Table 7. Transitioning from ICD-9 to ICD-10

	ICD-9-CM	ICD-10-CM
NUMBER OF CODES	• 13,600	• 69,000
CODING	• Mostly numeric • E and V codes alphanumeric. • Valid codes of three, four, or five digits.	• All codes are alphanumeric, beginning with a letter and with a mix of numbers and letters thereafter. • Valid codes may have three, four, five, six or seven digits.
DUPLICATE CODES	• Only ICD-9-CM codes are required.	• For a period of two years or more, systems will need to access both ICD-9-CM codes and ICD-10-CM codes as the country transitions from ICD-9-CM to ICD-10-CM. • Mapping will be necessary so that equivalent codes can be found for issues of disease tracking, medical necessity edits and outcomes studies.

The expansion of injury codes allows more complete data collection and standardization for the epidemiologic study of mortality and morbidity associated with unintentional and intentional injuries. In ICD-10 chapter XIX, S00-T98 Injury, poisoning and certain other consequences of external causes, replaces the N-code. S00-T14 reports **injury** codes and T15-T98 reports **poisoning and certain other consequences of external causes**. It must be recognized that ICD-10 external cause of injury mortality codes are very different than those in ICD-9, most notably, the E-code no longer exists. Replacing the E-code are V-, W-, X-, and Y-codes. In chapter XX V01-Y98 External causes of morbidity and mortality is further broken into:

- *V01–X59 Accidents*
- *X60–X84 Intentional self-harm*
- *X85–Y09 Assault*
- *Y10–Y34 Event of undetermined intent*
- *Y35–Y36 Legal intervention and operations of war*
- *Y40–Y84 Complications of medical and surgical care*
    - *Y40–Y59 Drugs, medicaments and biological substances causing adverse effects in therapeutic use*
    - *Y60–Y69 Misadventures to patients during surgical and medical care*
    - *Y70–Y82 Medical devices associated with adverse incidents in diagnostic and therapeutic use*
    - *Y83–Y84 Surgical and other medical procedures as the cause of abnormal reaction of the patient, or of later complication, without mention of misadventure at the time of the procedure*
- *Y85–Y89 Sequelae of external causes of morbidity and mortality*
- *Y90–Y98 Supplementary factors related to causes of morbidity and mortality classified elsewhere*

The NVSS data system has several strengths, including the ability to identify a geographic location, and the opportunity to examine death rates across regions or countries. Limitations include the lack of uniformity and specificity of death certificates across jurisdictions. There is limited information on the circumstances of the injury or contributing factors of death, and there is a significant lag phase from data acquisition to the publication of results.

- *National Ambulatory Medical Care Survey (NAMCS)*

This systematic random sample survey collects data on visits by patients to private physician offices. It has been used in recent years to identify office visits related to injuries. The National Center for Health Statistics (NCHS) trains the physician/staff to complete the survey in a sample of visits for a randomly assigned period of time. Demographic data and payment sources are also characterized regarding reason for the visit by the use of ICD-9 N-codes. A specific field added in 1991 asks whether or not the visit is injury-related, and since 1995 asked if it was work-related.

One limitation of the NAMCS is that the system is strictly voluntary, and therefore subject to potential biases in representation and generalizability. Further, the survey obtains estimates on patient visits, and not on the injuries or person injured. Also, many of the causes of injury based on E-codes are not specified because the E-code is not collected, which prohibits categorical estimates (e.g., motor vehicle). Thus, this system is not widely used in injury epidemiology.

- *National Hospital Discharge Survey (NHDS)*

The NHDS primary purpose was to measure inpatient care and hospital utilization. Researchers have used this data in the past to identify hospital admissions due to injury until the survey ended in 2010. National estimates of hospital use are determined by using a national probability sample survey that includes approximately 275,000 records from 500 short-stay non-federal hospitals. Data was collected from automated sources or manually abstracted from medical records. These included all hospital discharges except persons treated and released or persons admitted to long-stay or federal hospitals. The ICD-9 CM coding system for diagnosis and external cause of injury codes were used (N-, and E-codes), and this allowed one to distinguish injuries in the system.

This system only contains information on severe injuries requiring hospitalization, with the exception of injuries resulting in death prior to hospitalization. Unfortunately, a limitation of this system was the lack of information on the circumstances surrounding the injury event, such as mechanism and intent, particularly since less than 40% are E-coded (CDC, 2000).

- *National Hospital Care Survey (NHCS)*

This new survey integrates inpatient data formerly collected by the National Hospital Discharge Survey (NHDS) with the emergency department (ED), outpatient department (OPD), hospital-based ambulatory surgery location (ASL), and freestanding ambulatory surgery center (ASC) data as collected by the National Hospital Ambulatory Medical Care Survey (NHAMCS). Integrating these surveys now allows examination of the care provided across treatment settings, and by linking the survey data to the National Death Index and the Medicare Provider Analysis and Review (MedPAR) and Medicaid Statistical Information System (MSIS), a more powerful picture of patient care can be generated.

There are 112 primary sampling units, 500 hospitals, 250 freestanding ambulatory surgery centers included. Injury admissions are determined using the cause of injury ICD-9-CM E-codes or diagnosis codes. As with the NHDS, a weakness will be in under-reporting or failing to adequately document circumstances or mechanisms of injury.

- *National Hospital Ambulatory Medical Care Survey (NHAMCS)*

The NHAMCS data is sometimes used by injury epidemiologists to describe data on visits to US short-stay hospital EDs and outpatient departments (OD) (CDC, 1996).

A primary feature of this data is the availability of E-codes, place of occurrence, and alcohol or drug-relatedness for each visit. The N-code also indicates injury diagnoses and another variable records whether or not injury prevention counseling was provided to the patient. Data on age, gender, race and ethnicity and payer source are also collected. A vital addition began in 1995, when this system began distinguishing whether or not the injury visits were either unintentional or intentional in nature, and the addition of a narrative field descriptor.

A major limitation of this surveillance system is that it reports an estimate of national visits, not the actual frequency of injuries. Additionally, many of the E-codes do not specify categories for causation, most likely overestimating the unintentional-related events and underestimating the intentional-related events. While the OD component does distinguish between intentional and unintentional injuries, it unfortunately lumps the assaults with self-inflicted intentional injuries and those with unknown causes (CDC, 1996). The National Center for Health Statistics has compiled a 3-year descriptive summary on the ED data in an attempt to estimate the annual number of injury-related ED visits, which has provided some use to researchers attempting to fully understand the magnitude of the injury problem. (Burt, 1998).

- *National Health Interview Survey (NHIS)*

The NHIS is not frequently used in injury epidemiology, but can provide some information regarding injuries and poisonings through hospital utilization surveying. This system measures health status indicators from the US civilian population by conducting a continuous nationwide survey on a probability sample of 48,000 homes annually. The core questionnaire contains information on demographic characteristics and data on health issues, including injuries.

The occurrence of injuries in the previous 2 weeks are recorded in the survey. All injuries are E-coded and N-coded, providing the cause and nature and location. Beginning in 1996, more detailed questions on violence-related injuries were developed. Prior to this, information on injury was not differentiable by cause (e.g., assaultive vs. unintentional). In addition, there is ambiguity in the respondent's proxy regarding other household members, and this hinders the potential for detailed analysis. While this system attempts to report the amount and distribution of injuries recorded during the survey administration, it is a probability sample and is an underutilized data system.

Starting in 1997, NHIS redesigned the questionnaire and fielded a section devoted entirely to injuries and poisonings, now known as The Family Core Injuries & Poisoning Section. This section went through multiple revisions (1997-1999; 2000-2003; 2004-Present) but from 2004 on, included questions about injuries and poisonings that occurred to any member of the family within a three-month reference period for which medical providers were consulted. All injury and poisoning information continued to be provided by the family respondent.

One enhancement for data continuity beginning in 2004 was many open-ended, verbatim responses (body part injured and kind of injury) now had specific, categorical response options. For people who did not know the exact month, day, and year when the injury/poisoning occurred, additional questions were asked about the date of the injury/poisoning. Several questions (type of vehicle that hit pedestrian, cause of burn, type of animal bite, and whether the injury/poisoning caused any limitation of activity) were eliminated from the survey.

- *National Electronic Injury Surveillance System (NEISS)*

This widely used data system specifically identifies and quantifies risks of injuries associated with consumer products in the US by using a probability sample of 101 emergency departments (ED) statistically representative of hospital EDs in the US. Data are manually abstracted by nosologists and entered into an electronic database system. This information is later used to locate individuals to obtain specific information concerning the nature and cause of the injury.

Since this is only a sample of hospital EDs, injuries treated elsewhere are not reported. Only injuries associated with consumer products are reported, so a significant number of assaults not committed with one of these products would go unreported in this data system. Additionally, information about the severity of injury is not calculated since only one body part and diagnosis are recorded.

In October of 1993, the Study of Injured Victims of Violence (SIVV) was started for the Bureau of Justice Statistics at 1/3 of the NEISS hospitals, an improvement for surveying violence-related injuries (BJS, 1997). NEISS also began collecting information for the Centers for Disease

Control and Prevention (CDC) on nonfatal firearm injuries, whether or not they are violence-related or unintentional. Since the NEISS surveillance system was constructed to primarily monitor injuries, it is a heavily-used system with the injury field.

- *National Electronic Injury Surveillance System (NEISS-AIP)*

Maintained for over 30 years by the US Consumer Product Safety Commission, NEISS receives data on all injury-related visits to emergency departments from a stratified sample of 100 hospital emergency departments in the US and its territories. Each case collected has an associated statistical weight based on the inverse probability of being selected. Within the reporting format, information can be extracted on all injuries, particularly now with recent changes to include injuries which do not include specific consumer products. The NEISS-AIP uses an expanded definition of reportable injuries to include all nonfatal injuries and poisonings treated in U.S. hospital emergency departments, whether or not associated with consumer products. the NEISS-AIP uses a subsample (n=66 EDs) for its data collection amounting to roughly 500,000 injuries annually. Trained, onsite hospital coders abstract and code data for injury-related cases from ED records. Coded data and a narrative are transmitted electronically to the NEISS-AIP program where quality assurance coders review and complete the coding. Data are weighted to produce national estimates.

NEISS contains demographic data, injury type/severity/location, product involved, cause/mechanism of injury, intent of injury, principal diagnosis, locale where injury occurred and whether it is work-related. The NEISS data is available online and queries can be made based on a given product or demographic information. A major strength is the nationally representative sample that can be followed in a longitudinally.

Since only emergency department visits are included, a skewed view of sport injury is apparent. Data is often not available from the narrative sections and significant variation in narrative completeness and quality regarding injury mechanisms exists. Another constraint is determining whether the injuries occurred during organized sporting events, unorganized sporting events or recreational activities. For example if a boxing glove was reported, was this from a sanctioned fight or training/playing at home? The scenario may be difficult to ascertain.

NEISS-AIP collects demographic data, cause/mechanism of injury, intent of injury, principal diagnosis, locale where injury occurred and whether it is work-related.

- *National Automotive Sampling System (NASS-GES)*

The NASS is another surveillance system that is solely focused on injuries, albeit motor vehicle-related injuries. The purpose of this data system is to provide estimates of police-reported motor vehicles crashes. This is a probability sample compiled by the National Highway Traffic Safety Association (NHTSA) comprised of 17 states. Local police traffic crash reports are submitted to a central collection agency when incidents that result in an injury or property damage occurs or at least one vehicle is towed from the crash site. Data collectors routinely review all new police traffic reports to draw the sample for coding electronically. Information is available on crash location, vehicle characteristics, demographics and injury severity. Additionally, the length of hospital stay is recorded, serving as a proxy for severity and the reported lost work days. These are unique features to this dataset.

Some of the limitations of this system include the lack of state-specific information, and crashes not reported to police are obviously excluded from the national estimate, resulting in an undercount within the surveillance system. Additionally, data on injury, restraint usage, and drug or alcohol involvement depend on the police officers' subjective interpretation/observation at the crash scene. Finally, it is unfortunate that this dataset is not linkable to the Fatality Analysis Reporting System (FARS) dataset.

- *Fatality Analysis Reporting System (FARS)*

FARS is another injury surveillance system compiled by NHTSA to provide an overall measure of motor vehicle-related injuries by recording crashes on a traffic way that resulted in at least one fatality within 30 days of the crash event. This is the most comprehensive census of fatal motor-vehicle crashes in the US, and the standard in the injury field. Information is collected on the circumstances of the crash, including details on the occupants and the vehicle (person, vehicle, circumstance files). State-level analysts collect this information and then transmit the data to the central collection agency electronically. Additional key research features of the FARS dataset include the documentation of work-related fatalities for persons in the transportation industry.

Limitations of this surveillance system include potentially losing cases caused by intentional crashes (homicide & suicide) or legal intervention, incidents occurring entirely off a public roadway, and crashes resulting from natural disasters. Other limitations include the fact that the data is not comparable to death certificate data since E coding is not mandated, and medical information regarding the injury is generic in nature. For instance, no medical information other than injury severity and whether or not the person was taken to a medical facility is available only in limited circumstances.

- *Census for Fatal Occupational Injury (CFOI)*

The CFOI surveillance system is a compilation of work-related injury fatalities maintained by the Bureau of Labor Statistics (BLS). It examines data from multiple sources, including death certificates, workers' compensation reports/claims, and administrative records at both the state and federal level. The strength of multiple sourcing provides completeness and improves verification of events. Shared data collection responsibilities on decedents who were actively participating in work-related activities, or at the workplace during the injury occurrence also allows for a narrative description on incident occurrence and demographic information, providing a comprehensive data source of occupational injury deaths nationally.

Fatalities occurring outside work premises or among workers engaged in illegal activities (e.g., drug dealing) are excluded from the data system. The potential to overlook cases engaged in work activities independently or "under the table" would be missed, resulting in an undercount. In some cases there is insufficient detail to code circumstances. The CFOI system provides a valuable surveillance tool for reporting on the frequency, nature and distribution of fatalities in the workplace.

- *Survey of Occupational Injuries and Illnesses (SOII)*

The SOII is another data system compiled by BLS to provide national and state surveillance of work-related injuries reported by employer from the private sector. All job-related injuries that result in death, loss of consciousness, restricted work activity, transfer to another job or medical treatment beyond first aid are required by the Occupational Safety and Health Administration (OSHA) to be reported by employers. Information is gathered on fatalities, lost work days and nonfatal cases without lost work days and subclassified by industry. Another strength of this surveillance system is that information on demographics, nature of injury, and cause of injury are recorded.

Because this is a sample of injuries meeting OSHA reporting requirements, and excludes injuries requiring basic first aid treatment, this may well be a low count of the actual number of occupational injuries. The SOII complements the CFOI system since it generates an overall level and rate of nonfatal injuries and illnesses, by case type and industry, which are important for monitoring by injury epidemiologists with an occupational focus.

- *National Traumatic Occupational Fatality Surveillance System (NTOF)*

The NTOF surveillance system compiles all work-related injury deaths to workers 16 years and older with an external cause of injury code (E-code). It is prepared by the National Institute for Occupational Safety and Health (NIOSH), and draws from death certificates that contain a positive response to the injury at work item in an effort to fill gaps in the knowledge of traumatic work-related injury deaths. Strengths of this census include recording demographic characteristics (age, race, gender), employment status, cause of death and a narrative description of the incident, industry (Standard Industrial Classification codes) and occupation (Bureau of the Census occupation codes) performed at the time. This surveillance system provides important descriptive information regarding nature and magnitude of the occupational injury problem, the potential risk factors, which can lead to hypothesis formulation and setting strategic research priorities and prevention initiatives.

Worker deaths are underrepresented and the compilation is not as comprehensive as other data sources like CFOI. Also, relying on case identification in the death certificate for work-relatedness will also result in an undercount, especially since completion of this item remains an issue for verification. Employment information may be missing or uncodable for a high proportion of cases (up to 20% per data year). Since NTOF provides a nationwide surveillance system for occupational injury deaths based solely on death certificates for case identification it has been estimated to include an average of 81 percent of all occupational injury deaths nationwide when compared to CFOI. NTOF *was* the most comprehensive source of data on occupational injury fatalities prior to 1992, supplanted by the establishment of the CFOI system as the more accurate and utilized surveillance tool within injury research.

- *Behavioral Risk Factor Surveillance System (BRFSS)*

The BRFSS data system collects, analyzes and interprets state-specific behavioral risk factor data in order to plan, implement and monitor public health programs related to the major causes of mortality. This data is used to evaluate state-specific progress toward the Healthy People 2010 objectives. In recent years, measures related to injuries have been added to the BRFSS. In this system, data are obtained by state health departments by conducting random digit dialing of a sampling of adults in household with telephone. Individuals aged at least 18 years old are eligible, and persons younger, institutionalized or persons living in households without an operable phone line are excluded.

The core survey provides major demographic variables such as age, race and gender, and additional information regarding educational attainment, income, marital status, alcohol consumption and even drinking and driving habits. Beginning in 1988, an injury specific module was developed to probe for information related to smoke detectors, poison control, child passenger safety, and tap water temperature. Injury questions on child and adolescent safety were amended to the core questionnaire in 1993 regarding passenger restraint use, ability to swim and household fire escape plans. The swimming and fire safety questions were replaced in 1995 with questions about smoke detectors and bicycle helmet usage. An optional module related to firearm risks was also developed in 1995.

Since this is only a sample of households with telephones, the data system misses people of lower socioeconomic status without telephones. The data are subject to an undetermined degree of measurement error or bias due to reliance on self-report and lack of validity study. Additionally, since many components of the injury module are optional, sample size may limit detailed data analysis. It should be stressed that this surveillance system provides risk factor information related to specific injury mechanisms, rather than providing the frequency of the actual injuries sustained. For this reason, the primary use of BRFSS data has traditionally been by health planners to initiate safety or injury prevention programs aimed at the risky behaviors.

- *National National Violent Death Reporting System (NVDRS)*

The National Violent Death Reporting System (NVDRS) was designed in 2002 as an active surveillance system, with the intent to provide a census of violent deaths within the US. Ultimately, the purpose is to provide accurate, comprehensive and timely surveillance data aimed to help reduce and prevent the more than 38,000 suicides and 16,000 homicides reported in 2010.

Currently, 18 states participate by reporting on the following violent deaths:

- *Homicides*
- *Suicides*
- *Accidental firearms deaths*
- *deaths of undetermined intent*
- *deaths from legal intervention (minus legal execution)*

A major strength of the system is that the infrastructure required no additional data collection, the CDC simply provided a central repository and software to facilitate transfer of the multiple, complementary data. Data collected include the victim characteristics, incident information, toxocologic information, Table 8 shows the sources from which data on different topics is to be recorded.

Table 8. NVDRS Data Source Acquisition

Data Topic	DC	CME	PR	SHR	CFRT	LAB	ATF	USER
Case status								X
Number of persons & weapons								X
Incident narrative		X	X		X			
Document tracking								X
Person type (victim/suspect)	X	X	X	X				
Name, address	X	X	X					
Age/sex/race/ethnicity	X	X	X	X				
When and where (injury/death)	X	X	X					
Cause of death ICD code(s)	X							
Manner of death	X	X			X			X
Additional person descriptors	X	X	X		X			
Alcohol and drug tests		X						
Wounds	X	X	X					
Associated circumstances		X	X	X	X			
Victim-suspect relationship		X	X	X				
History of victim abuse		X			X			
Suspect was victim caretaker		X	X		X			
Weapon type								X
Firearm trace							X	
Firearm descriptors		X	X			X		
Poison details		X	X					
Weapon used by/on person		X	X	X				
Person purchasing firearm			X				X	

DC=death certificate; CME=coroner/medical examiner; PR=police record; SHR=Supplemental Homicide Report; CFRT=child fatality review team; Lab=crime lab; ATF=Bureau of Alcohol, Tobacco, Firearms, and Explosives.

Note: The hospital source was left out of the table to save space. It only captures whether inpatient or Emergency Department (ED) care occurred and what International Classification of Disease (ICD) codes were assigned.

Several limitations do exist, as quality depends on many steps from eliciting information at the scene by police or the coroner/medical examiner. The accuracy of the information could be suspect, or not documented. NVDRS abstractors might not be given full access to the report, or may improperly code or enter into the NVDRS system. With multiple sources and states, variability is likely across the states, limiting the reliability of cross-jurisdictional comparisons. Additionally, some data elements do not differentiate "no" and "unknown," making it difficult to interpret results and perhaps would lead to an artifact of reporting (e.g. the medical examiner in one state infrequently asks information compared to another). Further, the toxicologic testing policies, methods and screening detection limits does vary considerably across jurisdictions, limiting interpretability of the toxicologic data as well.

Building off of the NVISS pilot into an 18-state surveillance system is a critical step into developing a national system that would allow the CDC to provide information for every state to inform their prevention efforts. It will also ensure we have enhanced information on the national scope of the problem of violent deaths to monitor and track trends and to inform national efforts.

- *National Intimate Partner and Sexual Violence Survey(NISVS)*

The CDC's National Intimate Partner and Sexual Violence Survey (NISVS) is an ongoing, nationally-representative dual sample, random digit dial (RDD) telephone survey that collects detailed information on sexual violence, stalking, and intimate partner violence victimization of adult women and men in the US. The survey collects data on past-year experiences (incidence) of violence as well as lifetime experiences of violence (prevalence). First year survey data in 2010 provides baseline data and will be useful to track trends in sexual violence, stalking and intimate partner violence. In 2010, data were collected from 16,507 adults aged 18 and older (9,086 women and 7,421 men).

Physical Violence was defined by asking a series of questions:

- ***How many of your romantic or sexual partners have ever…***
  - *slapped you?*
  - *pushed or shoved you?*
  - *hit you with a fist or something hard?*
  - *kicked you?*
  - *hurt you by pulling your hair?*
  - *slammed you against something?*
  - *tried to hurt you by choking or suffocating you?*
  - *beaten you?*
  - *burned you on purpose?*
  - *used a knife or gun on you?*

Findings from the first year reflect 1 in 4 women (24.3%) and 1 in 7 men (13.8%) have experienced severe physical violence by an intimate partner (e.g., hit with a fist or something hard, beaten, slammed against something) at some point in their lifetime. Looking at all forms of IPV and the related impacts, approximately 1 in 7 (14.8%) women and 1 in 25 (4.0%) men experienced an injury as an outcome.

As with any RDD survey, there are questions about the representativeness of the sample, declining response rates (although the cooperation rate was high) and nonresponse bias. The estimates of the NISVS are likely to underestimate the actual prevalence, for several reasons. The respondent may currently be involved in a relationship and for fear of personal safety be less inclined to disclose violence. Some respondents may opt to conceal violence as being a victim may carry a social stigma, therefore reluctance may bias the survey data. With asking about a lifetime prevalence, recall bias may preclude accuracy among some respondents who might have experiences going back many years or decades.

2.1.2 State & Local Injury Surveillance Systems

- *Coroner Records*

The general role of the coroner is to incorporate the fields of medicine and forensics for the investigation of any sudden, unexpected, violent or suspicious death. Legal statutes mandate a coroner to investigate any death where the cause of death is unknown. Often, in order to determine the cause of death, an autopsy or postmortem exam can be ordered by the coroner.

Several types of fatalities fall under the jurisdiction of the coroner, and include, but not limited to, the following circumstances:

- From external violence, unexplained cause, or under suspicious circumstances.
- Where no physician is in attendance, or where, through in attendance, the physician is unable to certify the cause of death.
- From thermal, chemical, or radiation injury.
- From criminal abortion, including any situation where such abortion may have been self-induced.
- From a disease which may be hazardous or contagious or which may constitute a threat to the health of the general public.
- While in the custody of law enforcement officials or while incarcerated in a public institution.
- When the death was sudden and happened to a person who was in good health.

The manner of death is a classification of the way in which the cause of death came about, whether by force of natural events, accidental means, self-inflicted wounds, or other external forces. The coroner uses five manners of death, listed below:

1. *NATURAL*: Death caused solely by disease. If natural death is hastened by injury or any other non-natural event (ex: fall), the manner of death will not be considered natural. If the disease process is caused by a non-

natural event (ex: pneumonia due to long-term bed confinement as a result of a motor vehicle accident), the manner of death will not be considered natural.

2. *SUICIDE*: Death as a result of a purposeful action set in motion (explicit or implicit) to end one's life.

3. *ACCIDENT*: Death other than natural where there is no evidence of intent; i.e. an unintentional event or chain of events. This category includes motor vehicle accidents, falls, drowning, accidental drug overdoses, etc.

4. *HOMICIDE*: Death resulting from intentional harm (explicit or implicit) of one person by another, or by grossly reckless behavior.

5. *UNDETERMINED*: Manner assigned when there is insufficient evidence or information, especially about intent, to assign another manner.

In addition to classifying the manner of death, the postmortem examination (autopsy) on each decedent includes the preservation of evidence, various body fluids, and tissue for microscopic examination and toxicological analyses. Photographs are taken at autopsy both externally and internally for further documentation in cases where the pathologist must provide court testimony. The combination of manner of death and toxicologic information, demographics and surrounding circumstances produces a valuable tool for the injury epidemiologist to study the distribution and determinants of fatalities within smaller, more definable populations.

Table 9. Summary of State and Local Surveillance System Attributes

Surveillance System	Type of Injury Data	Injury Case Identification	Mis-classification	Sources of Injury Data
VITAL Statistics	Mortality	Coroner or Medical Examiner affirmation	False positives	Vital Statistics Record
HDD	Morbidity, Mortality, Incidence	ICD-09 coding	Miscoding	Hospital Record
ED	Morbidity, Mortality, Incidence	ICD-09 coding, Chief complaint narrative	Miscoding	ED Record
EMS	Mortality, Morbidity	Chief complaint narrative	Subject to Interviewer bias, personal	EMS Report

- *State-Based Hospital Discharge Data*

Hospital discharge data have been the source for several published injury reports. This is largely because hospital discharges are routinely monitored in many states. In these systems, data are generated from uniform hospital billing forms (UB-04) used to bill for hospital services. This form has a dedicated field for recording an E-code. As of October 1997, 42 states and the District of Columbia were collecting and managing statewide hospital discharge data sets. Of these states, 36 were routinely collecting E-codes, and 23 were mandating that E-codes be submitted for all injury hospitalizations (STIPDA, 1999).

Statewide hospital discharge data sets, like vital records, provide population-based injury data. This is a major difference and advantage when comparing the state level data to the NHDS probability sample. Like vital records, these data can be stratified by county and city. Hospital discharge data may be more useful than vital records for surveillance in less populated areas where some causes of injury death occur infrequently. Limitations though, exist as risk factor information is not recorded on hospital billing forms. Incidence rates may sometimes be inaccurate because of measurement problems in the hospital discharge data system. For example, if an injured person is treated at more than one hospital, the injury may be counted more than once, or if a person has multiple concurrent injuries some of them may not be counted. Also, hospital discharge data are affected by changes in the health care system that influences hospital admissions and coding practices. These changes may compromise the utility of these data for monitoring trends in injury morbidity.

- *Emergency Department Data*

As most injuries do not result in death or hospitalizations, the role of emergency department (ED) surveillance offers added value to the available mortality and hospitalization data by documenting injuries that are treated and released. State and local systems of ED surveillance offer the opportunity to capture more specific injury information than the NHAMCS system does.

Injuries treated in emergency departments that are not severe enough to require hospital admission are more common than injury hospitalizations. Thus, EDs provide a better source for tracking injuries that are common but not severe, providing key information to epidemiologists on the mechanisms of injury distributed across a smaller population base. Emergency department data may be useful for assessing injury prevention priorities in sparsely populated areas where injury deaths and hospitalization may occur too infrequently to be useful.

Moreover, emergency department visits may be less likely than overnight hospital admissions to be affected by changes in health care system. Therefore emergency department data systems, if they are population-based, may be superior to hospital discharge data systems for injury morbidity surveillance. Unfortunately, risk factor data such as the circumstances of injury and the use of safety devices are often not captured on emergency department records or hospital discharge.

When surveying the potential for national surveillance in 1997, it was discovered that 12 states and Puerto Rico routinely collect ED data. Eleven states were routinely collecting E-codes, with 9 states actually mandating E-coding for the patient record. However, states were not publishing surveillance reports based on these data (STIPDA, 1999). Thus, ED surveillance is not being widely used in the injury field.

- *Data Elements for Emergency Department Systems (DEEDS)*

One problem with ED surveillance is that data from multiple hospitals may vary due to differences in medical records assessment and completion. To overcome this hurdle, the CDC has embarked on a national project (DEEDs) to identify uniform data elements within EDs so that in the future, all EDs will provide information regarding the circumstances and nature of injury in a standardized manner. Uniform data definitions, coding conventions, and other recommended specifications would avert incompatibilities in ED records, substantially enhancing the utility of this type of injury surveillance. A further strength of DEEDS is the aim to incorporate the national standards into an electronic data interchange, or a computer-based record system. While this is a major advance for constructing a national, uniform injury surveillance system, the ambitious nature of the project remains an impediment.

Currently, DEEDS is slated for future review and revision by the CDC, with plans to coordinate a multidisciplinary evaluation for improving the first set of recommendations. The initial release of DEEDS was intended to serve as a starting point. Plans to expand the scope of DEEDS' coverage to provide comprehensive ED data records set a precedent for future revision and expansion. Since work on the next version is in progress, DEEDS is currently not being used.

- *Emergency Medical Services Data(EMS)*

Another source of surveillance is EMS. This data is collected from ambulance run reports for injuries and other medical emergencies. The data are most useful for assessing EMS transport times and the medical condition of the injured person upon EMS arrival and during subsequent transport to definitive care. EMS data may provide useful information for injuries, for example identifying the location of the injury incident, timing of injury, and neurological status of the victim. This type of surveillance data though remains relatively untapped as an epidemiologic resource.

The State and Territorial Injury Prevention Directors' Association compiled a consensus on datasets for injury surveillance (STIPDA, 1999). This recommended core injury surveillance activities and highlighted that effective surveillance can be achieved with access to just 2 of the 11 core data sets: vital records and hospital discharge data. All states have vital records data, and at least 36 states have E-coded hospital discharge data.

Injury surveillance can confirm, disprove or refine an analysis of an injury problem, and is essential for the design, implementation and evaluation of effective injury prevention and control programs for unintentional injuries. The data collected by these surveillance systems are valuable assets for public education and policy making, since both parties need to be well-informed regarding the magnitude of the unintentional injury problem. Examination of the injury problem requires investigation at the National, State and Local levels, considering both mortality and morbidity data, because the causes of these can differ. This section highlighted the major sources of this data, the strengths, limitations and potentials for conducting and improving the surveillance for unintentional injury.

2.2 EPIDEMIOLOGIC RESEARCH CONCERNING INJURIES

2.2.1 Introduction

The injury epidemiologic framework which developed over the past several decades was built largely upon the infectious disease epidemiologic methods. This framework includes the use of the epidemiologic triad as a model to examine the complex interactions of the host-agent-environment. It also includes the use of applied research techniques to quantitatively analyze relationships between exposures and injury outcomes. Through application of this scientific framework, injury researchers can develop a better understanding of the frequency of injuries, the nature of injury patterns, and the underlying etiology or contributing factors of the injury event. Assessments of injury risk factors typically begin with the descriptive epidemiologic designs to identify hypotheses of interest. Those hypotheses are subsequently tested with analytic epidemiologic approaches.

2.2.2 Descriptive Epidemiology

The purpose of this section is to illustrate the common descriptive epidemiologic methodologies as they are applied within the injury literature. The main objective of the descriptive epidemiologic study is to describe the frequency and distribution of existing variables. This is an essential and efficient step for generating hypotheses and measuring risks.

Descriptive methodologies include case reports/series, correlational/ecologic and basic descriptive studies. The most elementary design is the case report typically consisting of a narrative description of a single injury report examined at the clinical level. Often, this event is unusual in nature, whether by mechanism or severity, and is used to rouse other clinicians to look out for these sentinel events so they might quantify the magnitude or impact of the problem later. The extension of the single case report is the case series, where a number of case reports are collected over a larger base; typically with all cases seen at a single hospital. Where the case report shows an injury event has occurred once, the case series shows that it can become a repeated injury. Generally, the case series is confined to one reporting source over a defined time period. The multiple cases help to identify commonalities and variability among the cases that can lead to hypothesis generation in analytic studies.

An example of a case series report is a paper published in the Morbidity and Mortality Weekly Report on injuries associated with soccer goalposts. The authors examined all goalpost-related injuries reported to the Consumer Product Safety Commission (CPSC) from 1) the National Electronic Injury Surveillance System, 2) newspaper clippings, 3) medical examiner reports, and 4) personal contacts made by soccer coaches or equipment manufacturers to CPSC over a 14-year period. From 1979 through 1993, 27 persons were injured (n=9) or killed (n=18) from falling soccer goalposts. Most injuries (n=23) occurred among males, and the mean age of injured persons was 10 years. Head trauma was the principal cause of death in 14 of the fatal injuries and was diagnosed in two of the nonfatal ones.

Information from a case series report can help to identify specific factors which might be related to injuries. For example, 26 out of the 27 goalposts were made of metal, and most (n=23) were mobile, versus being permanently installed. The majority of the injuries (n=25) occurred when a goalpost fell forward, with the top crossbar striking the victim as many goalposts were not anchored (n=18). Not many of the events occurred during soccer games (n=4) and during practices (n=4), but during times not involving games or practice (n=19). As another example, consider how the injuries occurred. Injuries were associated with a person climbing (n=4), with a person swinging or doing chin-ups (n=7), with lifting the soccer goalpost (n=6), and with wind gusts (n=4). In 50% of the fatalities, the injured persons caused the goalposts to fall (n=9).

A third type of study, the descriptive epidemiologic study, examines a number of injury cases (numerator) within a population base (denominator) to calculate an incidence rate. This serves to garner more information regarding a specific injury type when little information regarding frequency and determinants are known. Additionally, rate calculations employ a standard measure for quantifying the injury burden on a population. The majority of descriptive studies depend on secondary data collection from existing sources (including several of the surveillance systems outlined previously) versus conducting primary data collection. This saves considerable time and resources, but still enables the researcher to examine person, place and time for specific injuries within a defined population.

A good example of a basic descriptive epidemiologic study using injury data was conducted among United States Marine Corps Officer trainees. This study investigated the injury incidence, injury rates and time off from duty within a defined population. The cumulative injury incidence was 60.8% and the injury rate was 3.9 per 1,000 training hours. This study provides information for future planning of injury management and preventive and intervention strategies (Kaufman, 2000).

Correlation or ecologic studies examine aggregate data to see if two factors are correlated with each other. Ecologic correlations look at rates compared to other characteristics between two or more geographic locations. This study type quickly gives researchers a quick assessment of whether or not an association exists and is worth investigating under more rigorous methods. Additionally, this design assists the researcher with hypothesis formulation as the foundation for the analytic study design phase. One injury study that employed an ecologic study design attempted to determine the effects of neighborhood levels of poverty on rates of injury among Hispanic versus non-Hispanic white children. The census block groups were the unit of analysis. The authors reported that neighborhood levels of household crowding were not related to injury among Hispanics, but neighborhood poverty was associated with lower injury rates, the converse was true among non-Hispanics. The authors concluded that cultural, geographic and socioeconomic differences appear to contribute to differences in childhood injury rates between ethnic groups (Anderson, 1998).

2.2.3 Analytic Epidemiology

Analytic study designs are distinctly different than the descriptive study designs previously summarized in that they test specific hypotheses. Many times the hypothesis concerns a particular exposure or risk factor that increases or decreases the likelihood of an injury outcome. Cummings further differentiated an exposure into two distinct types of injury studies: 1) injury causation or prevention in which the outcome is occurrence of the injury of interest, 2) injury treatment or prognosis in which the outcome may be death, occurrence of complications or another adverse or late effect of sustaining the injury (Rivara, 2000)

Under the analytic epidemiologic study designs, there are two major subgroups – observational and experimental studies. The following summaries provide descriptions of these designs and the application of these to published injury research studies.

Cross sectional

In a cross-sectional study design, observations of a study population are made at one time point. Both the subject's injury outcome status and exposure are measured at the same time, and this information is used to examine the relationship between the injury event and other pertinent factors. Since outcome and exposure are simultaneously collected, this limits the ability to test for causality. While this is an easy and efficient way to conduct a study or survey, and often reveals important associations and possible correlations, the temporal sequencing of cause and effect required for causal inference is not possible. One could argue that cross-sectional studies are really prevalence studies, used to calculate prevalence rates. For example, one cross-sectional study was designed to measure the prevalence of domestic violence among women and to test the association between experience of domestic violence and demographic factors through a survey (Richardson, 2002). A main outcome measure was to compare the recording of domestic violence in medical records with that reported in the self-administered questionnaire. Of the 1,035 respondents 425 (41%) had ever experienced physical violence from a partner or former partner for a lifetime prevalence rate. The medical records of 226 women were reviewed and 90 (40%) reported that they had ever experienced physical violence from a partner. Definite or suspected domestic violence was recorded in the records of 15 (17%) of these. Data extraction was validated in 107 sets of those medical records. The true rate of recording of domestic violence in the medical records of women was calculated as 7% (95% confidence interval 3% to 14%). In this study, a third of women who had experienced physical violence reported telling their general practitioner. The researchers suggested that under-recording of disclosure contributes to the gap between women's experiences and their medical records.

Case-Control

Another important type of observational study design is the case-control study. This design typically tests an association between an injury outcome and a previous exposure. In this design, the researcher selects a group of persons known to have sustained an injury event (cases) and compares them to another group of persons known not to have sustained the same injury (controls). Existing or past characteristics or frequency of exposure to a risk factor of interest is compared in the case and control groups. The resulting data is analyzed to provide estimates on the strength of association as well as possible statistical significance between exposure and injury outcome. The cases may be new cases or cases that have already occurred.

An injury-based example of the case-control study is illustrated in a population-based study in two cities to investigate whether access to firearms in the home increased the risk of suicide. The basic hypothesis under question was the rate of suicide should be higher given the presence of a firearm in the dwelling. For each case subject (suicide victim) data was compared to control subjects from the same neighborhood, matched with the victim according to sex, race, and age range. The investigators presented strong evidence that the presence of a firearm in the home increased the frequency of suicide in the home by over 4.8 times (Kellermann, 1992).

One of the major advantages of the case-control study design is that it can be used for rare events. Typically, severe injury is considered a rare event. So this design is well-suited to injury research. This type of study can also be used to efficiently study multiple risk factors for the same injury outcome once the case and control groups are selected. The major disadvantage, though, is the case-control study does not yield absolute risk, only a relative risk and does not show causality.

In the example from above, the researchers selected the case-control design to facilitate a retrospective analysis of a rare injury event involving firearms. By obtaining a significant relative risk, the researchers could justify prospective designs to explore the true risk of such events longitudinally when more resources such as time and funding are imperative.

Cohort

The cohort study is another example of an observational analytic study design, and can be either prospective or retrospective in nature. The cohort consists of a group of people sharing similar characteristics. The important step is to identify two groups within the study: 1) the exposed group; and 2) the nonexposed group. These groups are observed simultaneously over a defined time period and the major comparison is the incidence of the injury outcome between them. In a prospective design, the cases and controls are followed in real time into the future, looking for the incidence of the injury outcome, whereas in a retrospective design, the data of exposure and outcome have already been recorded and simply need to be reconstructed by the researcher. The historical data collected allows the researcher to go back in time and establish a follow-up period up to the present point, or study start.

When the injury outcome is common (such as mild injuries) and the follow-up period is not exceedingly long to measure incidence, the prospective study is favored. A recent prospective cohort study was conducted during 1996-1998 to evaluate the effectiveness of back belts in reducing the incidence of back injury within the occupational setting (Wassell, 2000). Back belt use was not significantly associated with a reduced incidence, or did not offer the hypothesized protective effect. (RR 1.22; 95% CI 0.87-1.70). Since this was the largest prospective study conducted on back belt use, and was adjusted for multiple individual risk factors, the researchers concluded that frequent back belt use was not associated with a reduced incidence of back injury.

The cohort study was selected by the researchers since previous research had established the injury outcome as a frequent occurrence versus a rare event. With the expectation of a high incidence over the study duration, researchers were able to adjust for confounding and produce a more accurate risk for back injury, as well as test the impact of a specific protective device.

If the injury outcome is rare and the follow-up period would be lengthy to measure incidence, the retrospective epidemiologic design can avoid these limitations. One cohort study that employed the retrospective design examined risk factors for re-injury among army airborne soldiers. Data were collected from this retrospective cohort by identifying lower extremity and lower back musculoskeletal in injuries from outpatient records. The researchers were interested in the magnitude of the increased risk associated with having a previous injury history. The observed risk of injury was seven times greater among previously injured soldiers when compared to injury-free controls. (Schneider, 2000).

Although cohort studies generally involve larger groups for analysis than case-control studies, and extend over time, requiring more funding to complete, they provide an incidence rate and a good assessment of levels of association between the exposure and outcome of interest. While association does not insinuate a concrete causal relationship, the relative risk does provide better information regarding absolute risk, which is another advantage over the case-control design.

Case-Crossover

The case-crossover epidemiologic design has just recently been applied to injury. It is now recognized in the injury epidemiology field. The case-crossover design has been proposed as a way to study events related to acute exposures. This design enables each case to serve as its own control and facilitates comparison of exposures that vary over time for an individual, while controlling for those factors that are invariant. In contrast, a case-control design enables analysis of both types of factors by comparing case and control exposures.

One of the first studies to apply the case-crossover design was a study on alcohol and injury (Vinson, 1995). The researchers wanted to determine whether and to what extent alcohol consumption increased the risk of injuries. They selected this design, classifying trauma admissions as rare events in relation to alcohol consumption as the intermittent exposure. When examining the exposed/nonexposed periods generated from interviewing patients at emergency departments, the researchers discovered the odds for injury was 2.5 (1 drink versus none) and 5 times greater (4 or more drinks versus 3 or less). They concluded that alcohol use immediately prior to injury was associated with an increased risk of injury, which was consistent with previously published dose-response effects.

While there are challenges to applying the case-crossover design in injury research, such as identifying the person-time at risk of the specific injury under study, getting exposure information prospectively, and identifying control periods that are at once similar to the time at which the injury occurred with respect to the baseline injury risk, the case-crossover design allows for a novel approach to evaluate factors that may lead to injury. This approach leads to freedom from confounding by differences between individuals that would be difficult if not impossible to overcome with more traditional approaches. Implementing such studies involves overcoming several important challenges just as in any other observational design.

Randomized Controlled Trials

The ideal candidate for conducting an experimental type of study is the randomized controlled trial. Compared to the observational types of studies, the experimental nature of the controlled trial gives the researcher the ability to assign risk exposures to the experimental and control groups, therefore providing the best answer about whether the exposure is causally related to the injury outcome. The randomization of subjects to the 2 or more exposure groups provides a balance on factors that may have otherwise influenced the outcome of interest. Randomization generates more confidence when observing differences in injury outcome between groups and the likelihood that those differences can be attributed to actual differences in exposures.

A recent study compared the effectiveness of training/equipment to reduce musculoskeletal injuries among healthcare workers employed a randomized controlled design (Yassi, 2001). This was a three-armed study (controls, no strenuous lifting, safe lifting only) among nursing staff with physical demands associated with patient transport and lifting. While participants subjectively reported less physical discomfort, pain and fatigue among the intervention arms, there was no objectively reported statistical significance for the incidence of injury, the primary outcome measure.

The randomized controlled trial in this example was considered the optimal epidemiologic design in order to evaluate an intervention aimed at reducing the incidence of injury. This rigorous methodology supplies advantages over the observational studies, which have limitations that are often an obstacle to the researcher. Still, they are often limited by financial resources, rare outcomes (low numbers) or lengthy follow up periods. The prospective nature and implementation of the intervention may not demonstrate measurable effects for quite some time. Koepsell also pointed out that “randomization may also sometimes be politically unacceptable to collaborating organizations or participants” (Rivara, 2000).

3.0 SPORTS INJURY EPIDEMIOLOGY

The epidemiology of sports injury in the U.S. can be problematic for researchers as comparing statistics across sports presents challenges including calculating the number of participants involved, and the time played as well as potential differences in the definition of injury. In order to properly quantify sports injuries, epidemiologists need to quantify injury occurrence with respect to who, where and when and what is the outcome.

According to the National SAFE Kids campaign and American Academy of Pediatrics, each year In the U.S., about 30 million youths participate in organized sports activities, resulting in over 3.5 million injuries. Nearly one-third of **all** injuries in childhood are sports-related injuries. Most commonly, these injuries are sprains/strains and generally cause time loss from sports participation. According to NEISS, more than 775,000 children, ages 14 and younger, are treated in hospital emergency departments for sports-related injuries each year. Leading mechanisms of the injuries are falls, being struck by an object, collisions, and overexertion during informal sports activities. Consider these estimated injury statistics for 2009 from the Consumer Product Safety Commission (CPSC):

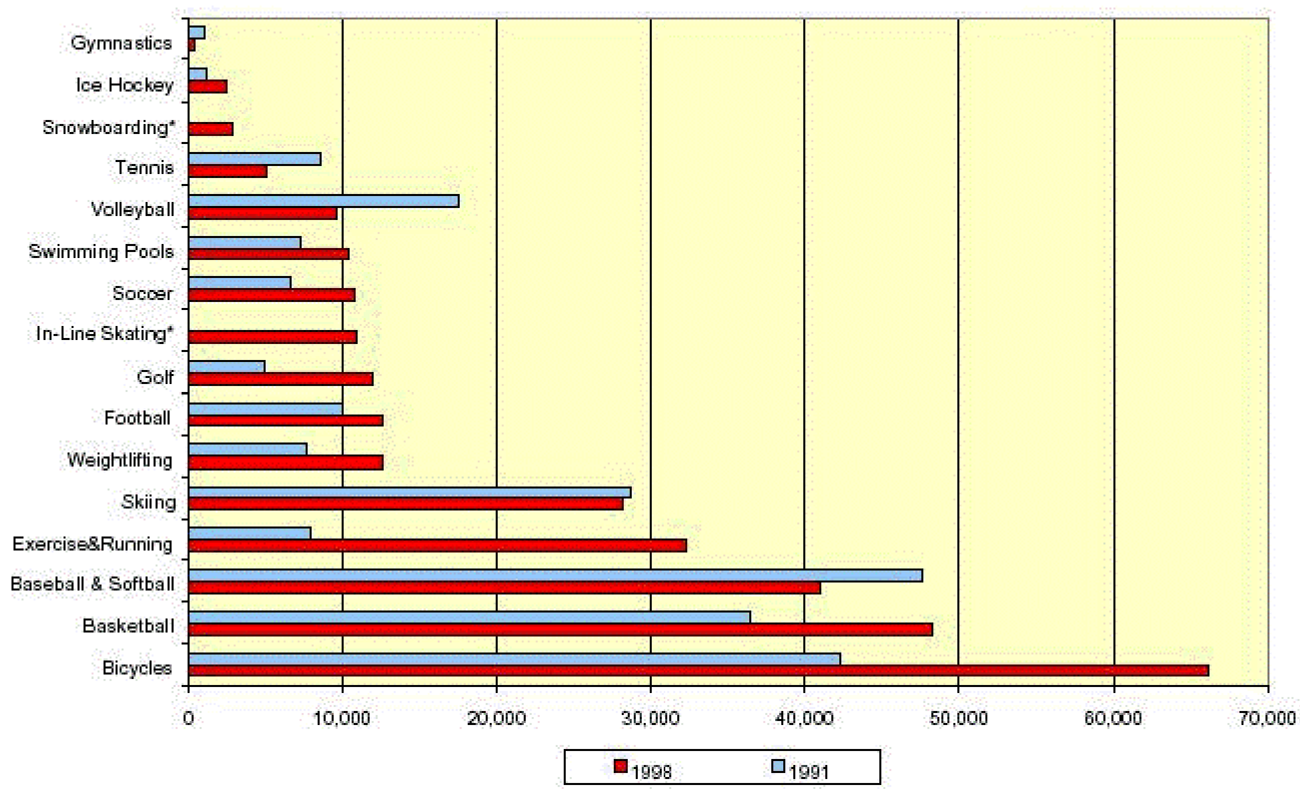
- ***Basketball.*** *More than 170,000 children ages 5 to 14 were treated in hospital emergency rooms for basketball-related injuries.*
- ***Baseball and softball.*** *Nearly 110,000 children ages 5 to 14 were treated in hospital emergency rooms for baseball-related injuries. Baseball also has the highest fatality rate among sports for children ages 5 to 14, with three to four children dying from baseball injuries each year.*
- ***Bicycling.*** *More than 200,000 children ages 5 to 14 were treated in hospital emergency rooms for bicycle-related injuries.*
- ***Football.*** *Almost 215,000 children ages 5 to 14 were treated in hospital emergency rooms for football-related injuries, with nearly 10,000 of those hospitalized as a result of their injuries.*
- ***Ice hockey.*** *More than 20,000 children ages 5 to 14 were treated in hospital emergency rooms for ice hockey-related injuries.*

- ***In-line/roller skating.*** *More than 47,000 children ages 5 to 14 were treated in hospital emergency rooms for in-line skating-related injuries.*
- ***Skateboarding.*** *More than 66,000 children ages 5 to 14 were treated in hospital emergency rooms for skateboarding-related injuries, with more than 4,500 children hospitalized as a result of their injuries.*
- ***Sledding/Toboggan.*** *More than 16,000 children ages 5 to 14 were treated in hospital emergency rooms for sledding-related injuries.*
- ***Snow skiing/snowboarding.*** *More than 25,000 children ages 5 to 14 were treated in hospital emergency rooms for snowboarding and snow skiing-related injuries.*
- ***Soccer.*** *About 88,000 children ages 5 to 14 were treated in hospital emergency rooms for soccer-related injuries.*
- ***Trampolines.*** *About 65,000 children ages 14 and under were treated in hospital emergency rooms for trampoline-related injuries.*

With varying degrees of contact, some sports are considered riskier than others (e.g., football versus swimming). However, all sports have an injury potential ranging from acute traumatic incidents to chronic injuries emanating from overuse or misuse of a body part. The highest rates of injury occur in sports that involve contact and collisions.

Although death from a sports injury is rare, the leading cause of death from a sports-related injury is a brain injury. Sports and recreational activities contribute to approximately 21 percent of all traumatic brain injuries among American children. Almost 50 percent of head injuries sustained in sports or recreational activities occur during bicycling, skateboarding, or skating incidents. Most of the severe injuries occur during individual versus team sports and over 62% of the reported injuries occur not during competition, but during practices.

In the last 20 years, there has been a significant increase in the number of adults who participate in sports. Public health authorities have encouraged this trend because of the widely recognized benefits of physical activity as a way to combat the epidemic of obesity and coronary artery diseases. However, a considerable increase in the incidence of sports injuries in all types of sports has been observed The increase of sports injuries, particularly among adults is now being considered an emerging public health problem. According to a U.S. CPSC report, sports injuries among baby boomers increased by 33 percent from 1991 to 1998. Figure 5 shows over a 7 year period, there was a sizeable increase in the hospital emergency room-treated injuries to persons 35 to 54 in 1991 (276,000) when compared to 1998 (365,000). This trend in increasing injury continues, as in 2006, NEISS reported over half a million injuries just for basketball. Another two million injuries were associated with bicycling, football, other sports.



SOURCE: U.S. Consumer Product Safety Commission, Directorate for Epidemiology, National Electronic Injury Surveillance System (NEISS)
** NOTE: In-line skating and snowboarding were new sports in the 1990s. Injury data were first collected for in-line skating in 1993 (4,310 estimated injuries) and snowboarding in 1994 (1,520 estimated injuries).*

Figure 5. Estimated Number of ED Treated Injuries, 35-54 Years of Age by 16 Popular Sports Categories, 1991 and 1998

The data further showed the boomer population suffered more than 1 million sports injuries which cost over $18.7 billion in medical expenses in 1998. The highest numbers of sports-related injuries came from bicycling, basketball, baseball, and running. The largest number of deaths were associated with head injuries while riding a bicycle. Most of these injuries resulted from accidents with motor vehicles due to heavy traffic, poor visibility, or failure to obey traffic regulations. Drowning while swimming was the next most common cause of death, followed by skiing accidents. Swimming where there is no lifeguard increases the risk of drowning if a person should get a cramp, or have some other serious problem.

The following lists the injury estimates for adults and leading causes from the 2006 NEISS data:

- *529,837* ***Basketball*** *- Cut hands, sprained ankles, broken legs, eye and forehead injuries.*
- *490,434* ***Bicycling*** *- Feet caught in spokes, head injuries from falls, slipping while carrying bicycles, collisions with cars.*
- *460,210* ***Football*** *- Fractured wrists, chipped teeth, neck strains, head lacerations, dislocated hips and jammed fingers.*
- *275,123* ***ATVs, Mopeds, Minibikes*** *- Riders of ATVs were frequently injured when they were thrown from vehicles. There were also fractured wrists, dislocated hands, shoulder sprains, head cuts and lumbar strains.*
- *274,867* ***Baseball, Softball*** *- Head injuries from bats and balls. Ankle injuries from running bases or sliding into them.*
- *269,249* ***Exercise, Exercise Equipment*** *- Twisted ankles and cut chins from tripping on treadmills. Head injuries from falling backward from exercise balls, ankle sprains from jumping rope.*
- *186,544* ***Soccer*** *- Twisted ankles or knees after falls, fractured arms during games.*
- *164,607* ***Swimming*** *- Head injuries from hitting the bottom of pools, and leg injuries from accidentally falling into pools.*
- *96,119* ***Skiing, Snowboarding*** *- Head injuries from falling, cut legs and faces, sprained knees or shoulders.*
- *85,580* ***Lacrosse, Rugby, & other ball games*** *- Head and facial cuts from getting hit by balls and sticks, injured ankles from falls.*

Note that in several activities, as highlighted in these data, head injuries are a frequent outcome from sports and recreational activities. Increasing attention is now being given to concussion and its effects in both the short- and long-term. For example, recent reports note a higher frequency of concussion related to NFL football. A major effort recently commissioned by the National Football League (NFL) reported that Alzheimer's disease or other similar memory-related diseases appear in the league's former players at 19 times the normal rate for men ages 30 through 49. Other studies have found that football players who suffered concussions were more likely to suffer from depression.

Boxing is another high contact sport with widely documented head injury. Recently, boxers who are exposed to repeated head trauma show a higher risk of progressive Parkinson's disease. Other sports that that expose the head to repeated impacts, such as boxing, soccer, ice hockey, football, rugby are currently being investigated to assess risk and reduce the propensity for head injury. While many sports have injury from incidental head contact, many combat sports (such as mixed martial arts, kickboxing, Muay Thai permit head contact, therefore a greater potential exists for both acute and chronic neurologic injuries. The following section outlines the current surveillance mechanisms underlying sport and recreational injuries and the current understanding of injury related to combat sports.

3.1 SPORTS INJURY SURVEILLANCE SYSTEMS

In the previous chapter, several general surveillance systems were described that exist to monitor injuries in the broadest sense. While that broad array of data is useful for understanding the extent and mechanisms for general types of injuries they do not specifically focus on collecting sports-related injury information. The following section highlights the major injury surveillance systems established to garner that information and generate reporting on the frequency, distribution and nature of sports injuries.

3.1.1 National Electronic Injury Surveillance System (NEISS-AIP)

The NEISS-AIP system is one of the most common surveillance systems used to identify sports and recreational injuries in the United States. It examines sports and recreational injury requiring medical attention in the emergency department setting. Further, NEISS-AIP collects demographic data, cause/mechanism of injury, intent of injury, principal diagnosis, locale where injury occurred and whether it is work-related.

There are limitations that come with using the NEISS-AIP data ranging from narrative completeness and quality to other constraints such as determining whether the injuries occurred during organized sporting events, unorganized sporting events or recreational activities. For example if a boxing glove was reported, was this from a sanctioned fight or training/playing at home? The scenario may be difficult to ascertain.

Using the WISQARS online system, an estimated 30,024,936 unintentional injuries (all causes) at an age-adjusted rate of 9,735.7/100,000 were reported for 2011. Looking specifically at sport-related injuries, the highest frequencies of injury were in basketball (680,307), football (413,620) and baseball (170,902).

3.1.2 RIO™ (Reporting Information Online)

The RIO system is internet-based surveillance software developed by The Research Institute at Nationwide Children's Hospital (Columbus, Ohio) as the centerpiece of Dr. Dawn Comstock's injury surveillance research. The software was developed in 2004 to provide a time and cost effective injury surveillance tool for research in large, geographically dispersed populations of high school athletes (9th-12th grades). It is a real-time and flexible data collection tool that allows contributors to input, revise and update data. Injury data captured are used to identify the rates, patterns and trends among physically active participants to drive the development of evidence-based, targeted interventions to prevent or control injury. A reportable injury was defined as according to the following criteria:

- *An injury that occurs as a result of participation in an organized high school competition*
- *Requires medical attention by a team physician, certified athletic trainer, personal physician, or emergency department/urgent care facility and*
- *Results in restriction of the high school athlete's participation for one or more days*

The software is extremely well suited to surveillance by allowing multiple administrations of the same questionnaire prospectively. As a result, both exposure data and outcome data from the study population can be ascertained. Data reporting is performed by Athletic Trainers, who document exposure information (number of competitions and practices), and reportable injuries sustained by student athletes of each sport. Trainers submit injury reports that collect demographics (age, year in school, etc.), the injury (site, type, severity, etc.) and the injury event (position played, phase of play, etc.). Once submitted, updates with additional severity and time loss information can be added.

The original HS RIO™ study examined data reported by 100 nationally representative schools for 9 sports of interest (boy's football, soccer, basketball, wrestling, baseball; girls' soccer, basketball, volleyball, softball). It projected 1,392,262 nationally estimated injuries. The combined injury rate per 1,000 athlete-exposures was 2.17 (4.26 competition; 1.40 practice). When using the expanded HS RIO™ study of a convenience sample of US schools reporting for all sports of interest, that rate is 1.80 (3.64 competition; 1.19 practice. The convenience sampling includes additional sports such as track, lacrosse, swimming, cheerleading, field hockey, ice hockey, gymnastics).

Recently launched in 2011-2012 is the Middle School RIO™ Study, which conducts surveillance on a national sample of middle school aged football players, and their reported injuries. This surveillance system was modeled after the National Collegiate Athletic Association Injury Surveillance System (NCAA ISS) and High School RIO™.

3.1.3 National Collegiate Athletic Association (NCAA)/Datalys

Since 1982, the NCAA maintains a nationally representative injury surveillance system (ISS) for intercollegiate athletics covering an array of both men's and women's sports. Participation in the NCAA ISS is voluntary, therefore not random, but all NCAA institutions are encouraged to participate. Reporting is conducted by the athletic trainers, given the task of data collection and entry. The collection and assessment of relevant injury data is used to appropriate injury prevention health policy based on evidence.

A reportable injury in the NCAA ISS was defined as:

- *one that occurred as a result of participation in an organized intercollegiate practice or contest*
- *necessitated medical attention by ATs or physicians*
- *resulted in restriction of the student-athlete's participation for 1 or more days beyond the day of injury*

The athletic trainers document the sport, date of injury, sport-relatedness, time of season, event type, injury mechanism, activity before injury, whether the injury was incident or recurrent, whether the injury was chronic or acute, side of the body, whether the athlete had surgery, injured body part, type of injury, diagnosis, outcome, date of full return, and total days out due to injury.

The NCAA currently outsources the ISS system to Datalys, a national nonprofit organization which conducts injury research, specific to injury surveillance and sport research. Datalys warehouses and manages the data for improved quality control and data integrity. The current ISS uses online data entry replete with export functionality for analysis.

With 30 years of surveillance conducted, the NCAA ISS allows a comparison of injury trends and rates, a major strength of the system. Critical components for injury surveillance such as injury occurrence, severity, and exposure are methodologically sound and while not random, it does represent a national sample of collegiate level sports. Because the focus is solely at the intercollegiate level, other injuries are missed, including intramural or recreational athletes. Data access outside the athletic trainer network requires review by the NCAA and Datalys in order to gain access, and once approved, the (Datalys Injury Statistics Clearinghouse) is made available. Another drawback recently has been that the summary reports by sport are no longer produced for the public and restricted for NCAA use exclusively. In order to gain further access to the NCAA ISS information, the Datalys Center provides a process for obtaining NCAA de-identified line item data from the NCAA's Injury Surveillance Program. Researchers are required to fill out an online application outlining research proposals including: specifics aims, statistical methodology, and what specific data they are requesting to access. This application is reviewed by the Datalys Center's Independent Review Committee where it is approved, returned for clarifications, or denied. After approval from the IRC, the application packet is sent to the NCAA for approval. Contingent upon the approval of the NCAA, the datasets are made available to the researchers.

From recent peer-reviewed publications, it is reported that the NCAA ISS collected over 200,000 injury and 1.4 million exposure records during 1988-2004. As a result of multiple and changing data collectors variability in defining injury events was evident. In order to reduce this variation Inclusion Criteria were defined to produce a standardized sample. This filtering and injury evaluation resulted in an elimination of approximately 9% of the injury and 4% of the exposure records, resulting in a usable database of more than 182.000 injury and 1,300,000 exposure records. A total of 83% of the injuries were categorized as new, whereas 17% were categorized as recurrent.

3.1.4 National Center for Catastrophic Sport Injury Research

The center collects and disseminates data on death and permanent disability sports injury data that involved brain and/or spinal cord injuries (catastrophic injury). Partnering with the NCAA, the American Football Coaches Association and the National Federation of High School Associations the center routinely produce reports catastrophic sport injury and catastrophic football injury. Data is gathered on catastrophic injuries from information provided from the National High School Federation, NCAA ISS, United States Lacrosse, print newspaper services and Google searches. Cases are typically followed up by phone conversation or questionnaire to track more detailed information. By its nature, data is limited to catastrophic injuries and doesn’t represent a full picture of all injuries in any single sport.

According to the 20th annual report, during a 20 year period (1982-2002) the total number of direct and indirect fatalities among high school athletes was 256. Of these, 88 were from basketball, 47 from track and field and 22 from football.

3.1.5 National Boy Scout Jamboree

In 1985 during the Boy Scout jamboree, a system was implemented to analyze patterns of injury to assist Scout planners for future activity. By identifying hazards, immediate interventions and preventions of future injury was the major objective.

Using a standard injury report form, all referrals to the army hospital during a 13-day period from the jamboree were documented. Boy scout liaison nurses completed the forms which included demographic data and the reason for visit/referral. Injury visits further recorded the time, date, nature of injury as well as the site and activity performed at the time of the incident. Verification of the injury reports were conducted by an investigator using the medical record.

An overall incidence of 8.5 injuries (per 10,000 person days) was reported. The most common injuries were sprains (39%) and contusions (24%) to the upper and lower extremities. Falls were the most frequently noted cause of injury, accounting for 76/179 (42%) of all reported injuries. The highest rates were noted to occur during bucking bronco (14.4) and BMX racing (11.4).

On day 4 of the jamboree, a tropical storm struck, causing an increase in injuries from being struck by falling debris. Over 1/3 of the storm-related injuries were as a result of poorly constructed gateways falling from scouts seeking shelter from the torrential rain and heavy winds.

The injury surveillance system developed for the 1985 Boy Scout Jamboree was a simple and inexpensive, yet sensitive way to track and report injuries from athletic and recreational events during a well-defined population in a temporary encampment. Nearly half of all the referrals to the hospital were attributed to injuries, and a major outcome to intervene and prevent similar injuries in future jamborees was a result. For example, the bucking bronco was an unacceptable risk and the ride was discontinued midweek, and not featured in following years.

3.1.6 FIS (International Ski Federation) Injury Surveillance System

FIS developed an Injury Surveillance System (ISS) for the FIS disciplines prior to the 2006-2007 winter season. Aimed at reducing the number of injuries suffered by elite athletes, the FIS ISS research project is led by the Oslo Sports Trauma Research Center. The specific objectives of the FIS ISS project include monitoring injury patterns; monitoring trends in injury risk across the disciplines; and providing background data for in-depth studies of the causes of injury for particular injury types in specific disciplines, such as serious knee and head injuries. This project provides FIS with current and reliable data on injury trends at the elite or world cup level so that appropriate steps to address the risk factors through FIS rules and regulations, as well as obtaining a basis for providing proper injury prevention programs can be taken.

During the first 2 seasons, only about half of all injuries occurring in the World Cup events was reported, so in order to address the under-reporting, the FIS enlisted team doctors, local organizers, and the athletes, coaches and other medical personnel. The injury form is designed to be self-report, but athletes are encouraged to enlist medical support for better and more sensitive reporting, as by definition, a reportable injury is one incurred during training or competition requiring medical personnel attention.

Data is kept confidential and only available in aggregate reports. Current data report that nearly 1/3 of world cup athletes experience a time-loss injury and 1/3 of these were so serious that more than 28 days of training or competition was lost as a result. The highest risk was to alpine skiers, freestyle skiing and snowboarding with an average of 30 injuries per 100 athletes per season. The Nordic disciplines of ski jumping, nordic combined and cross-country skiing, ranked much lower (below 10 injuries per 100 per season). Knee ligament injuries were followed by concussions as the most common injury type.

4.0 EPIDEMIOLOGY OF COMBAT SPORTS INJURY

Combat sports by nature are competitive contact sports where two combatants fight against each other under certain rules of engagement. Typically, this simulates real hand-to-hand combat in varying degrees and use various skill sets such as punching in boxing, kicking in taekwondo and karate, elbow and knee striking in Muay Thai and Khmer boxing. There are also grappling based sports that concentrate on obtaining a superior position as in freestyle or Collegiate wrestling, or using throws such as in judo and Greco-Roman wrestling, or the use of submissions as in Brazilian jiu-jitsu. Modern mixed martial arts (MMA) competitions incorporate a wider range of attacks permitting both striking and grappling techniques.

Due to the nature of striking, throwing or immobilizing an adversary, combat sports are generally considered more dangerous and risky compared to other athletic activities. Some opponents have gone as far to seek banning fighting, claiming the nature of deliberately attempting to inflict damage and injury an opponent is not a sport. [McCain] This perception is often anecdotally perpetuated and polemic in tone. Injuries from combat sports have been scantily catalogued within peer-reviewed medical literature, and the published studies are largely descriptive with the aim to report incidence or prevalence within particular combat sports.

With the surge in popularity in several combat sports over the past several years, it is imperative to establish surveillance systems that adequately collect injury information, to quantify the frequency and nature of recorded injuries and to analyze the determinants and causal factors associated with injury. As reviewed in the previous chapter, the major sports and recreational injury surveillance systems have limitations for covering combat sports. There is often ambiguity in the designation of an injury as being from an organized sports versus recreational activities unless clearly documented within narrative fields. So, while NEISS-AIP may contain combat sports injuries, it does not constitute a system designed with the specificity needed. Within the organized sports systems for both the NCAA and HS-Rio, wrestling is the only combat sport surveillance conducted.

The purpose of this chapter is to review the current research on injury with specific attention given to the range of combat sports that involve striking, such as boxing, traditional martial arts, kickboxing and mixed martial arts.

Within injury research, the epidemiologic triad is a model that helps with understanding the frequency, distribution and determinants of injury to combat sport athletes, or fighters. The transfer of energy becomes the agent of injury, primarily mechanical or kinetic energy exchanges during striking in a fight or competition. The abnormal transfer of mechanical energy most often results in a traumatic injury, for example, blunt force trauma from being struck by a punch, kick, knee or elbow. This chapter will focus on this type of injury outcome among fighters within several key combat sports as reported in the literature.

4.1.1 Boxing

Boxing is a combat sport in which two people fight each other exclusively using their fists for competition (2 points of contact) and are permitted to target the head and torso (2 body regions). Combatants' hands are wrapped, then gloved per sanctioning guidelines. Boxing is typically supervised by a referee engaged in during a series of one- to three-minute intervals called rounds, and boxers generally are of similar weight. There are four ways to win; if the opponent is knocked out and unable to get up before the referee counts to ten seconds (a knockout, or KO) or if the opponent is deemed too injured to continue (a Technical Knockout, or TKO), if an opponent is disqualified for a rule infraction or if there is no stoppage of the fight before an agreed number of rounds, a winner is determined either by the referee's decision or by judges' scorecards.

While no single surveillance system exists to track boxing injuries, several studies outlined in Table 10 have used medical report forms for gathering injury information (Zazryn, Timm). The majority of the injuries in these studies were deemed superficial, such as facial lacerations, contusions, with the exception of concussions. In Zazryn’s 2003 study, 15.9% of combatants were classified as concussed, and even lower (6.1%) in Timm’s research. One reason to explain the differential is that the exposures in several of Zazryn’s reviews involved actual fights and among professional boxers. Timm conducted his research at the US Olympic Training Center, and this was a population of elite amateur boxers where the majority of the exposure was during training and sparring activities versus actual fights.

Table 10. Summary of Boxing Injury Literature

Author	Injury Definition	Severity Level	Exposure (Boxing)	Experience (Pro vs. Amateur)
Dudek (2011)	Self-report questionnaire	Duration of training break caused by injury, recuperation time	1. Training 2. Sparring 3. Fighting 4. Outside sports hall	Boxing/kickboxing clubs, unspecified level (n=41 boxers)
Pappas (2007)	NEISS cases relating to boxing activity, apparel and equipment; ED probability sample	Mostly treated & released with 10.3% of boxing injuries requiring hospitalization	Not enough detail, as NEISS review was based on scanning primary activity	Unknown
Potter (2011)	NEISS cases relating to boxing activity, apparel and equipment; ED probability sample	ED treatment	Compared injuries related to punching bags versus all other	Unknown
Timm (1993)	Self-report, sought medical attention	A very small % classified as "serious" if they could not be immediately treated by typical services of USOTC athletic trainer	Several: 1. Sparring 2. Training 3. Fight	Elite Amateur
Zazryn (2003)	Accredited ringside doctor exam	With exception of concussion (15.9%), most were not severe	Fight	Pro
Zazryn(2006)	Observational report from trainer or researcher -any physical damage that occurred to the head, neck, arms, or trunk during any boxing related activity	1. it was brought to the attention of a fight doctor; 2. it prevented the continuation of a fight/training/sparring session; 3. it required medical treatment (either self or professionally administered)	1. Training 2. Sparring 3. Fight	Pro & Amateur
Zazryn (2009)	Ringside physician report	Majority lacerations to head/face treated on site	Fight	Pro

One strength of the medical report format in surveillance is that medical staff evaluate the incident as reported by the boxer. A limitation of this system, however, is that many less severe injuries will go under reported as boxers may self-treat superficial injuries and not seek medical attention. In a self-report study utilizing a questionnaire, Dudek looked at a small group of boxers across all training exposures (training in a sports hall, sparring, fighting, training outside the sports hall). While the level of boxer (pro versus amateur) was not reported, the majority of injuries reported were during fighting and training and were contusions, and dislocations/ligament strain. The boxers cited insufficient warm up and too high intensity in the activity as potential contributing factors leading to injury.

Another source for tracking boxing injuries used by Pappas and Potter was the examination of relevant data in the NEISS system. Both authors sought cases reporting boxing activity, apparel or equipment within the ED probability sample. However, based on the nature of the NEISS system, knowing what the true exposure or activity was in detail becomes difficult, as well as the skill level of the injured. In both reviews, the majority of the persons reporting to the ED were fractures, contusions and sprains, with relatively low reports of concussions in both studies (3-5%). Compared to Zazryn, who reported 16% concussion among professional boxers, we begin to see a differential in reporting based on the experience and intensity of boxing activity. The self-report and medical reports target boxers participating in traditional training activities, whereas the NEISS system would report a greater range in activity from children playing to weekend warriors using a product such as the heavy bag at home and sustaining injuries with perhaps little regard to safety or prevention.

4.1.2 Kickboxing

Kickboxing generally refers to a group of martial arts and stand-up combat sports based on kicking and punching (4 points of contact). The term kickboxing can be widely applied to activities ranging from self-defense, general fitness, or as a contact sport. As a contact sport, it broadly includes all stand-up combat sports that allow both punching and kicking, including Savate, Muay Thai, Indian boxing, Burmese boxing, Sanshou, styles of karate, etc. In a more narrow sense, kickboxing is restricted to the styles that self-identify as kickboxing, for example, Japanese kickboxing or American kickboxing (4 points of contact) and permitted to strike the head, body and sometimes the legs (2-3 body regions).

Similar to boxing contests, round durations and the number of rounds can vary depending on the skill of the fighters. Generally, professional fighters fight a longer round and more rounds in a fight than amateurs. A winner is declared during the bout if a fighter quits or fighter's corner throws in the towel, knockout (KO), or referee stoppage (technical knockout, or TKO). If all of the rounds expire with no knockout then the fight is scored by a team of 3 judges. The judges determine a winner based on their scoring of each round. A split decision indicates a disagreement between the judges, while a unanimous decision indicates that all judges saw the fight the same way and all have declared the same winner.

Table 11. Summary of Kickboxing Injury Literature

Author	**Injury Definition**	**Severity Level**	**Exposure**	**Experience (Pro vs. Amateur)**
Dudek (2011)	Self-report questionnaire	Duration of training break caused by injury, recuperation time	1. Training 2. Sparring 3. Fighting 4. Outside sports hall	Boxing/kickboxing clubs, unspecified level (n=30 kickboxers)
Lloyd (1998)	Case report	Sought medical treatment for injury (ED)	Training	Unknown
Romaine (2003)	Self-report questionnaire	Level 1: discomfort with no change in activity Level 2: modification in normal exercise routine Level 3: alteration in daily activity	Cardio Kickboxing exercise session	Instructors & Participants
Zazryn (2003)	Ringside physician exam	Aside from concussion (17.5%) superficial	Fight	Pro

Perhaps the relatively obscure sport of kickboxing would explain why such scant literature on injuries exists. In fact, the literature reviewed in Table 11 shows quite an array in exposure, activity and the injury case definition. The Romaine article reports uniquely on kickboxing for fitness, and not for competition. It was a self-administered questionnaire given to participants and the instructors in cardio kickboxing classes. The majority of the injuries reported where strains to the back, knee and hip, and several cases of tendinitis from "overuse". The authors also showed a relationship to the beats per minute of the music and higher incidence of injury 1.5 times more injuries when over 140 bpm. Simply put, increased speed of the workout lead to more injury. This is a very different level of activity compared to a fight or even fight training and sparring and therefore not directly comparable to the information garnered by Dudek or Zazryn, who targeted kickboxers involved in the competitive sport aspect.

Zazryn acknowledged very little data on injuries to kickboxers, even citing the case report from Lloyd, who had a person claim he was a kickboxer in training and ruptured a tendon while doing pushups. While pushups may constitute a portion of the strength and conditioning regimen of a kickboxer, the actual exposure was outside the realm of the sport. Dudek also examined training outside the sports hall, such as running or "roadwork" noting a few small number of insignificant injuries, with the bulk coming from heavy training or fighting. While Dudek reported frequency of injury and attempted to assess severity based on recuperation time, no information was presented on location of injury or body part. Zazryn noted the majority of the kickboxing injuries over a 16-year period to professional fighters was to the head/neck/face (52.5%) followed by the lower extremities (39.8%). Concussions accounted for 17.5% of the total injuries, again showing that within a professional fighter population a higher proportion recorded.

One of the limitations with the Zazryn study was they failed to differentiate the styles of kickboxing, and then examine injuries within each style. As different scoring targets exist, it would be conceivable that different injury patterns would be produced. For example, kickboxing under full-contact rules may limit contact to above the waist, whereas Muay Thai allows kicks to the lower extremities. This may lead to a differential in head injuries between the sport. A strength of this study was the authors noted a difference in injury outcome whether winning (30.1%), losing (62.9%) or drawing (7%) with the opponent. This would suggest the nature and perhaps severity of injury may impact the fight outcome, and was the only study to report this in the literature. They did not compare the subgroups of winners to losers to determine whether the injury patterns were similar or not.

4.1.3 Muay Thai

Muay Thai is a combat sport from Thailand that uses stand-up striking along with various clinching techniques. It is similar to other south east Asian kickboxing systems, namely pradal serey from Cambodia, tomoi from Malaysia, lethwei from Burma and Muay Lao from Laos. Muay Thai is referred to as the "Art of Eight Limbs" or the "Science of Eight Limbs" because it makes use of punches, kicks, elbows and knee strikes, thus using **eight "points of contact"**, as opposed to "two points" (fists) in boxing and "four points" (hands and feet) used in other more regulated combat sports, such as kickboxing. Muay Thai also allows strikes to all 3 body regions (head, body, legs).

Table 12. Summary of Muay Thai Injury Literature

Author	Injury Definition	Severity Level	Exposure	Experience (Pro vs. Amateur)
Gartland (2001)	Self-report; face-to-face interview	Number of missed training days (enforced absence due to injury)	Contact level: 1. None, 2. Touch Sparrin 3. Full contact 4. Fight	Pro & Amateur
Gartland (2005)	Self-report to medic or referee report	Not specified	Fight	Amateur
Shirani (2011)	Physician referral to maxillofacial surgeon	required physician treatment; injury screened radiographically	Training & Fight	Pro & Amateur

Only three studies surfaced within the peer-reviewed medical literature, two by the same author (Gartland). In the first study, the authors conducted 1-to-1 interviews using a questionnaire asking about injuries incurred both in training and at competitions. Strengths of the study included assigning a level of contact, how experienced the participant was, and what the contact level was during the injury. So an attempt to frame the circumstances surrounding the event. However, with this being a retrospective recall of injuries in a 6-month and 12-month window, bias was acknowledged and more severe injuries were less likely to be forgotten than minor or superficial trauma.

The majority of the injuries among all groups of experience were contusions, and to the lower extremities. Of prominent note was the considerably higher concentration of injuries to the lower extremities, which differs from the patterns reported in the boxing and kickboxing literature, where the head was most often reported as the primary injury site. When looking further into the sample, the authors reported that comparing across the experience levels, the professionals reported the higher percentage of head injury compared to amateurs and total novices (42.5% to 31% to 2.3%). This may perhaps suggest that with increasing experience comes a higher level of skill and precision in attacking one's opponent, further, the use of protective equipment may factor into why such a striking differential was reported. Time off training was reported as a proxy for severity of injury with little difference across the groups.

Gartland followed with a prospective investigation of injuries sustained during amateur fight competitions, particularly to address the issue of recall bias in the first retrospective study. This was the first study on injuries and injury rates in competition. As the competition was sanctioned by the International Amateur Muay Thai Federation (IAMTF) in the UK, standards for protective equipment and rules were applied to all bouts. Injuries were recorded by the fighter, referee or on site medic (when seeking treatment). Over the course of 10 competitions, 92 total fighters were assessed, and injury rates were reported by weight class. Lightweights reported the lowest rate at 1.3 injuries per 100 minutes of competition compared to 30/100 among heavyweights. The mean was 2.38/100. Authors attributed this astronomical difference to an insufficient sample size among the heavyweight division. One finding that was striking was the almost complete absence of lower limb injuries, which was previously reported as being so high in the retrospective study. Perhaps the insistence on using protective shin guards during fighting led to a lower incidence, coupled with what the authors reported as what practitioners cite as an acceptable injury or don't perceive this as an injury for reporting.

Shirani's study was designed to assess the prevalence, distribution, pattern and types of oral and maxillofacial trauma incurred by 95 athletes aged 18-25 in boxing, taekwondo, kickboxing and Muay Thai. They found a prevalence of 80% of sustained at least 1 traumatic injury to the face requiring treatment by a physician. Data included injury type (facial laceration, facial fractures, jaw dislocation, tooth fracture, displacement, luxation, and avulsion, etc.), site of facial injury (jaw, nose, malar bone, teeth, etc.), the causative sport (boxing, taekwondo, kickboxing, and Muay Thai) and demographic data were recorded. Injuries were severe enough to warrant physician referral to a maxillofacial specialist for further clinical and radiographic consultation and treatment.

Of the original sample of 120 subjects reporting for physician assessment, 95 male subjects (79.2%), had at least one facial injury including laceration (69.2%), fractures (45.1%), dental injuries (44.2%), and dislocation (6.7%). Statistically significant differences were documented when comparing injuries and the sports; kickboxing caused the most maxillofacial injuries and was identified as more injurious relative to the other 3 sports. Tooth fractures (59.7%) were the most common dental injuries, and the nose (84.7%) was the most frequently fractured facial bone. Lacerations were more common in Thai-boxers (93.3%). Another important finding was that injuries were significantly greater in professional (86%) rather than amateur (42%) fighters. In this study, prevalence of facial injuries from combat sports professionals was significantly high (roughly 80%), especially in kickboxing. Kickboxing was the most injurious of these combat sports and caused the most significant number of maxillofacial trauma, especially to the nose and teeth.

One limitation of the study was that the activity beyond the sport itself was not documented, meaning, the exposure and circumstances and mechanism were not included in the findings. While all injuries were severe enough to warrant expert medical attention, it was not possible to ascertain whether the activity was actually a fight or training, what equipment was worn, the cause of the injury. When reviewing the literature previously on boxing and kickboxing, and now Muay Thai, we have established variation in rules and techniques that can create sizeable differences in injury outcome given the nature of the sports themselves, while related are still quite distinct.

4.1.4 Mixed Martial Arts (MMA)

Mixed Martial Arts (MMA) is a full contact combat sport that allows the use of both striking and grappling techniques, both standing and on the ground, including boxing, wrestling, Brazilian jiu-jitsu, Muay Thai, kickboxing, taekwondo, karate, judo and other styles (8 points of contact). The roots of modern mixed martial arts can be traced back to the ancient Olympics where one of the earliest documented systems of codified full range unarmed combat was utilized in the sport of Pankration. The modern version of this combat sport developed in Brazil from the 1920s (vale tudo) and was introduced to the United States in 1993 as the Ultimate Fighting Championship (UFC).

During the initial years, the term "no holds barred" was more popularly used, but with the evolution of standard rules the sport is now highly regulated today. Originally promoted as a competition pitting distinct martial arts styles against one another to determine the ultimate fighting art, the modern version now employs multiple martial arts into essentially a single style of combat, hence the name "mixed" martial arts.

Table 13. Summary of Mixed Martial Arts (MMA) Injury Literature

Author	**Injury Definition**	**Severity Level**	**Exposure**	**Experience (Pro vs. Amateur)**
Bledsoe (2006*)	Ringside physician exam	Not recorded	Fight	Pro
Buse (2006)	Research review of fight video	Hierarchy 4 salient categories of stoppage: head impact; musculoskeletal stress; neck choke or miscellaneous trauma	Fight	Pro
Ngai (2008)	Ringside physician exam	Not recorded	Fight	Pro
Scoggin (2010)	Ringside physician exam	ED referral when indicated	Fight	Pro

**1st MMA Injury incidence paper*

The relatively recent emergence of MMA as a popular combat sport in terms of participation would serve to explain the scant information on injuries within the literature. The very first published article by Bledsoe in 2006 utilized the state of Nevada athletic commission's data during the early 2000's. Additional research conducted since then by Ngai and Scoggin also sought to report on MMA injuries using state athletic commission data documented by ringside physicians at the events. Similar to the boxing injury literature, ringside physicians are present to assess fighters post outcome and report to the athletic commission under government regulation. To date, all of these studies were retrospective in nature, examining risk factors with adjustment for factors such as age, weight and match outcome.

Interestingly, in the 3 studies utilizing the athletic commission reports, all exposures were professional fights, with very similar rates of injury ranging from 23.6 to 28.6 injuries per 100 fight exposures. MMA has drawn comparisons to boxing in terms of risky sports, and the rates reported in boxing (17-25%) by Bledsoe and Zazryn are fairly equivalent. Further, in all studies, facial lacerations ranked and the most commonly reported injury. One possible explanation is that the type of glove worn during MMA bouts is quite different than boxing gloves worn in boxing, Muay Thai and kickboxing. The open glove, which allows competitors to use fingers for grappling, have more edges or seams, and is a smaller weight (4 oz versus 8 oz in other sports).

Important differences in injury outcomes were noted both by Bledsoe and Ngai, discovering that losing fighters were at greater injury risk than others. While Bledsoe also noted older fighters were at additional injury risk, Ngai was unable to report that difference to be statistically significant within that study. Further differences were noted in that Bledsoe reported increased fighting times, such as matches lasting more than 3 rounds lead to increased injury, with Ngai only able to note an association lacking statistical significance.

One last study explored MMA injuries utilizing a rather radical approach of reviewing publicly available footage of 642 fights from 1993-2003 to determine injury incidence, type, mechanism and demographics, including fighting background. The only statistically significant finding among outcomes and characteristics was that fighters who lost compared to fighters who won using the same technique (e.g., head impact, choke) were older. This suggests, along with Bledsoe and Ngai, that more exploration of age and fight outcome (win vs. loss) is associated with a potential elevation in injury risk. One drawback to Buse's study was that there was no breakout of facial lacerations, just head impact, which ranked as the leading cause of injury (28.3%). They reported a remarkably higher predicted concussion rate of 48.3/1000 fights, whereas Zazryn's kickboxing rate was 19.2/1000. A likely explanation for the spread is the difference in assessing concussion from a ringside physician versus video replay. Buse's team made the assumption that any fight ending from head impact, would likely result in a concussion, quite liberal and likely overestimation.

4.1.5 Traditional Martial Arts (TMA)

In the broadest sense, the martial arts are systems of combat that are practiced for a variety of reasons, including self-defense, competition, physical fitness, as well as mental, physical and spiritual development. The term martial art has become heavily associated with the fighting arts of eastern Asia, but is also used to refer western combat systems as well such as fencing, for example. Some martial arts are considered 'traditional' and tied to an regionally ethnic, cultural or religious background (such as karate, kung fu, hapkido), while others are modern systems developed either by a founder or an association (such as krav maga or systema).

There is a broad range of techniques taught that include weaponry (swordsmanship, stick fighting etc.), grappling and striking to be used across several distinct applications such as self-defense, combat sport, choreography or demonstration of forms, physical fitness, meditation.

TMA cross over into sports when forms of sparring become competitive, becoming a sport in its own right that is sometimes dissociated from the original combative origin, such as with western fencing. Often, these sport forms of traditional martial arts are featured in Summer Olympic Games, including Judo, Taekwondo, western archery, boxing, javelin, wrestling and fencing as events. Practitioners in some arts such as kickboxing and Brazilian Jiu-Jitsu often train for sport matches, while in other traditional styles such as aikido or wing chun kung fu refrain from participating in sport type competitions. Within TMA there are a variety of rules that range from only kicking above the waist and punching the torso, as in Olympic style tae kwon do, to full contact karate allowing similar striking to Muay Thai with the same 8-points of contact to 3 body regions.

Table 14. Summary of Traditional Martial Arts (TMA) Injury Literature

Author	**Martial Arts involved**	**Injury Definition**	**Severity Level**	**Exposure**	**Experience (Pro vs. Amateur)**
Beis (2007)	Tae kwon do	Self-report to tournament physician	Time loss evaluation	Fight	Amateur
Birrer (1983)	shotokan karate, tae kwon do, kung fu	Self-report & independent observation	Classified 63% "minor"	1. Training 2. Fight	Amateur
Birrer (1988)	broadly defined martial arts	NEISS cases relating to martial arts activity, apparel and	Mostly mild to moderate with only 5% requiring hospital admission	Not enough detail, as NEISS review was based on	Amateur

Table 14 Continued

		equipment; ED probability sample		scanning primary activity	
Halabchi (2007)	tae kwon do	Self-report or referee report to ringside physician	Grade 1: unable to continue fight Grade 2: unable to continue tournament Grade 3: hospitalization	Fight	Amateur (Black, Brown, Purple rank)
Lystad (2008)	Tae kwon do	Varied (14 meta-analysis prospective cohort)	Varied	Varied	Amateur
McLatchie (1981)	karate	Case series at infirmary (anecdotal summation)	Hospital treatment	Fight	Amateur
McPherson (2010)	karate, jujitsu, tae kwon do, judo, kick-boxing, tai chi	Self-report, sought ED treatment	Severe (26%) admitted or required follow up medical treatment	Training (50%) Fight (20%)	Amateur
Pieter (2005)	tae kwon do	Literature review (8 studies)	Varying definitions	Training Fight	Amateur
Siana (1986)	tae kwon do	Self-report sought medical officer	4% hospitalizations, majority to head/neck	Fight	Elite Amateur
Zetaruk (2005)	Shotokan karate, aikido, tae kwon do, kung fu, tai chi	Self-report questionnaire	Time off from training; major classified as 7+ days off (immobilization/ surgery	Did not specify	Amateur

One of the most striking observations when reviewing the literature on TMA injuries is how different the population or sample is. There are substantially more participants that are children, women and the entire experience level is amateur. While rankings exist within the specific styles, competitors do not compete for fight purses, and even at the elite amateur levels such as the Olympic games, there are regulations and protective equipment requirements enforced to prevent injury.

One of the stronger methodological studies conducted by McPherson, used a population-based hospital ED surveillance system. Age-standardized rates showed males had a higher incidence (6.9/10,000 vs. 3.1/10,000). There were differences across the styles reported, with karate (33%), taekwondo (14%) and judo (12%) as the top three. Injuries were mostly due to falls (33%) and strikes (32%) with 21% resulting in fractures as the leading nature of injury. While karate and taekwondo only involve striking, and judo throwing, logically, the falls were mostly attributed to judo and the striking injuries to karate and taekwondo.

Zetaruk conducted a 1-year retrospective study also comparing several styles of TMA with respect to injury outcomes. This study focused almost exclusively on training participation, versus fight exposures. They examined predictor and outcome variables and concluded that the different martial arts present different injury patterns. Surprisingly, in this review, gender was not a significant predictor for injury outcome. Additionally, older participants were more likely to be injured than younger ones, as well and more experienced martial artists at greater risk than the inexperienced. Training time or the exposure to the sport itself was a significant predictor of injury. There may be an interaction between age and experience that combines for a significant risk factor that needs to be explored. While cross-sectional in nature, no causal relationships can be claimed, but the suggestions for these detected relationships provide good direction for future research.

Lystad performed a meta-analysis isolated to competitive taekwondo only pooling prospective cohort studies to eliminate recall and selection bias. The result was 14 pooled studies with a range in methodological rigor from “poor” to “moderate”. The latter studies were rated higher, often reporting incidence, injury location, injury type, injury mechanism and 2 reported severity (Koh & Sherrill). In these studies, there was no evidence to suggest age, gender or level of competition affects injury risk, but as the included studies had methodological shortcomings, it is difficult to draw concrete conclusions as differences limit comparisons and interpretations. As often noted in the injury research, variable definitions of injury, exposure and populations present ongoing challenges. Future epidemiological studies, whether isolated to one specific combat sport or several need to establish uniformity and standardization for conducting proper surveillance, sampling, data collection and even so specific as to rate reporting.

4.1 STUDY METHODS

Combat sports by design involve a range of striking, throwing, or immobilizing the opponent and therefore are commonly considered more dangerous compared to other athletic activities. However, simply relying on anecdotal reports alone is inadequate. Despite of the popularity of combat sports, most studies on the incidence of injuries involve either a small sample size (Zazryn, 2006) or report injuries during tournaments (Gartland, 2005; Halabchi, 2007; Siana, 1986). Additionally, there is disagreement in the literature about the incidence of injuries in combat sports; some studies suggest that combat sports are more dangerous for the participants compared to other sports (Jarrett, 1998) while others claim that the rate of injuries in combat sports is comparable or lower to that of other popular sports like football, basketball, and soccer (Birrer, 1988).

Within the reviewed literature in the last chapter, this author noted that there are consistent differences in the methodological approaches to reporting combat sports injuries. Primary differences both within and across the combat sports categories (boxing, kickboxing, Muay Thai, mixed martial arts and traditional martial arts) exist:

- Surveillance approaches/data collection
- Case definitions
- Exposure
  - time
  - activity/intensity
- Sample characteristics
  - Age ranges
  - Experience or rank of combatant
- Mechanism of injury
- Nature of injury
- Severity of injury

In order to implement effective intervention strategies, important foundational work needs to be done. Profiling the problem and surveillance data collection is a critical first step in order to truly begin to research and identify risk and protective factors within combat sports. This is a difficult endeavor to begin to construct surveillance in an area of sports and recreational activities that has garnered considerably less attention over time than more popular sports within the United States. In terms of attempting to quantify American participation in combat sports activities, Simmons Market Research estimated that 18.1 million Americans participated in karate or some other form of martial art at least once in the past year, which amounted to 9.4

million adults, 5.5 million teenagers, and 3.2 million children. Further, 28% of the adults indicated participating “every chance they get.” Of the adults, 52% are men and 48% are women with the majority aged 18-34 years (63%). The Martial Arts History Museum reports that 100+ colleges have martial arts programs. Martialinfo.com, a leading martial arts website, there are an estimated 30,000 martial arts schools across the US alone. As with much market research, since research design is often undisclosed and proprietary by nature, it comes with caveats when interpreting the reports without knowing the methodology. The Simmon’s report may include individuals engaged in combat sports, but with a probable range of participation levels, from fitness to competition making denominator estimates difficult.

Having reviewed the established literature provides information on the strengths and weaknesses of past approaches and serves as a starting point for developing stronger surveillance approaches in order to advance the knowledge of combat sports injury.

5.0 RESEARCH METHODS

MuayThai has undergone rapid growth within the past few years as a global fight sport with increasing numbers of participants. The inclusion of MuayThai into the General Associations of International Sports Federations (GAISF) has allowed this sport to become a member of the Olympic mainstream. This was an exceptionally important development as MuayThai, under the World MuayThai Council (WMC) and International Federation for MuayThai Amateur (IFMA), has a suited position equal to other sports such as Football (FIFA), Basketball (FIBA), and the other Olympic recognized martial arts.

Increased recognition of MuayThai has led to increased participation. In 2010, IMFA estimated global participation to be 1 million. The growth in MuayThai participation will likely carry an increase in both sports- and recreation-related injury risk. The risk of physical injury is inherent in combat sports, particularly MuayThai. However, the frequency, nature and determinants of injury in this setting is not known largely because injury surveillance systems have yet to be established to actively collect this information. Generating this information is a critical first step toward the broader goal of improving the health and safety of MuayThai fighters engaged in competition.

The current research in understanding injury in MuayThai is limited. In previous studies dealing with MuayThai, three major weaknesses are evident. One, interviews of MT participants were limited to gyms and events, therefore only active participants were captured in the sample, and those using MT for recreational purposes for physical fitness training were excluded. Two, previous reports have not established a clear case definition of injury, with the potential that repeated injury rate may be biased by differing perceptions of what in injury in MT is. Three, Recall bias within the retrospective study designs utilized likely resulted in the underreporting of minor injuries.

Based on these weaknesses, our current research project looks to primarily:

- Improve the surveillance for injuries by establishing an online system that would allow participants to report information without significant subject burden.
- State a clear injury definition
- Identify the exposure in MT as a FIGHT

The overall goal of this dissertation project is to improve surveillance of injury in MuayThai competitions. Improved surveillance is necessary for a proper understanding of the frequency and potential risk factors for MT related injury; and can lead to future interventions to improve the safety of participants in the sport. This work will scientifically address the following aims.

To develop and evaluate three recruitment approaches for the surveillance MuayThai fight-related injuries. One approach was to recruit fight participants in person at the fight event; a second was to email fight participants directly after the fight event; a third approach was to have the sanctioning body email fight participants directly, on behalf of the investigators.

To assess the viability of these approaches by examining differences in the contact rates, cooperation/response rates and refusal rates between the approaches. Further, this research will qualitatively assess the recruitment approach and method for maximizing contact and participation.

To describe the frequency and severity of MuayThai fight-related injuries identified from the collective surveillance effort and explore underlying demographic factors associated with the injury outcomes.

To study the determinants of MuayThai fight-related injury in the collective surveillance sample and identify if:

fight-related injury is related to years of fight experience.

Hypothesis: MT fighters with less fighting experience will have higher injury frequency and severity than fighters with greater experience.

fight-related injury is related to degree of protective equipment worn by participants.

Hypothesis: MT fighters wearing less protection during fights will have higher injury frequency and severity compared to fighters wearing more protection.

fight-related injury is related to pre-existing injury.

Hypothesis: MT fighters with previous injury leading up to a fight will have higher injury frequency and severity in the competition than fighters without training-related injuries.

5.1.1 Target Population and Sampling

The target population for this evaluation is MuayThai fighters. Currently, it is unclear what the rates of participation are within the sport of MuayThai as there is no centralized governing body that currently records participation for estimating what the population is. What currently exists is a fragmented collection of sanctioning bodies and athletic commissions with considerable variability in influence and representation. Within several western countries, however, regional, high-profile communities exist with more active participation through prominent events. In these regions, the fight events are governed by the local athletic commission, and sanctioned by the World Kickboxing Association (WKA). Sanctioning establishes a clear and concise rule set, approved by the athletic commission for legal competition. Promoters host an event with matchmaking conducted under the auspices of the WKA to ensure fair and appropriate matching (e.g., weight classes, experience, are some factors considered critical in matching). The fight functional hierarchy is depicted in Figure 6 in order to show how fighters are selected for fights and would therefore be eligible for sampling. Because of the uniformity in rules, and a higher number of fight events, these regions were targeted for subject recruitment.

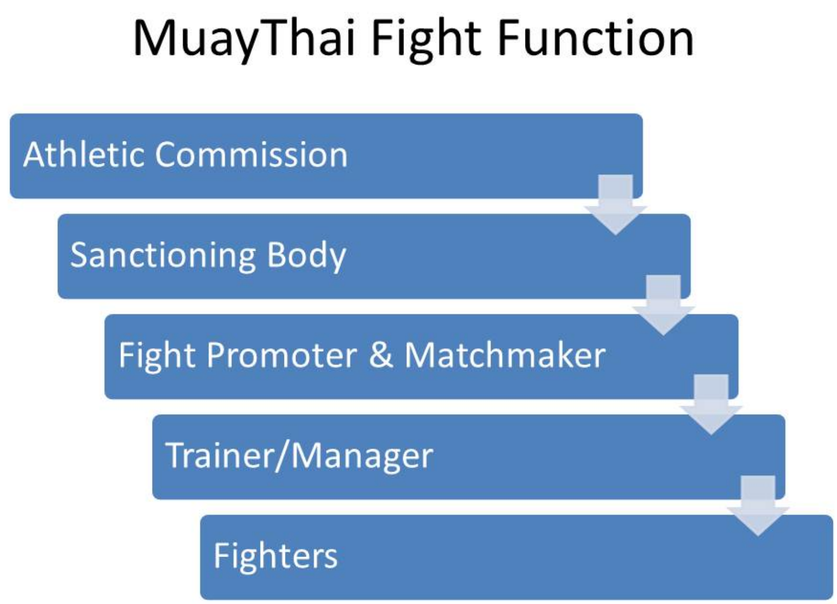


Figure 6. Muay Thai Fight Functioning

We employed one of the most common types of nonprobability sampling, a convenience sample. Fighters were recruited using emails and social media to announce the survey by several sanctioning bodies in the United States, Canada and the UK. Anyone with access to the URL would be able to participate. We used individuals available within the above mentioned high profile regions rather than attempting selection from an unknown population. This resulted in 154 respondents that completed the survey.

A second group was recruited using a targeted approach. Nine fight events were randomly drawn over the study period, and ten fighters were then randomly drawn for recruitment using 1 of the 3 recruitment approaches (Figure 7). These went sequentially so that the in-person recruitment was done at fights #1, #4 and #7 (3 fights total); direct email was sent for fights #2, #5 and #8 (3 fights total); indirect email was sent for fights #3, #6 and #9 (3 fights total). Of the 90 approached fighters, 41 completed the survey (45.5%).

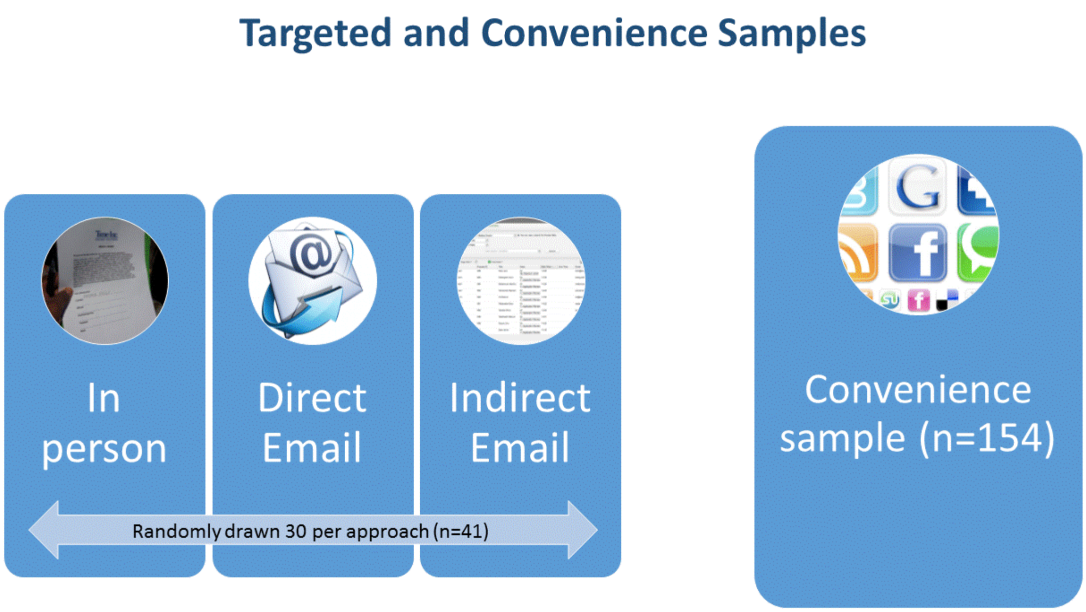


Figure7 . Research Study Sampling

This resulted in an overall study population comprised of 195 fighters that participated in sanctioned fights across North America and the UK. While not entirely an accurate representation of the population, we acknowledge the potential sampling bias, meaning that the results from a study conducted with such a sample cannot be generalized to the population as a whole, as this is not a probability sample. Additionally, as the survey sponsor is a respected and trusted member of the international sporting community, recruitment was more viable and somewhat easier given personal reputation and routine contact. As the major aims of this study were to improve the surveillance capabilities and injury definition for MuayThai, we wished to describe our sample in an exploratory way. In an ideal sampling frame, we would operationally define a target population from which a probability sample would be drawn to get an accurate representation of the population, and this can be developed as a future goal.

Subjects who agreed to participate were recruited from legal and sanctioned fight events that use a standardized set of rules for competition as approved from the sanctioner. The rules for competition are fairly unique to the sport of MuayThai, although some regional variability can occur. What this convenience sample does not include is unsanctioned fights or events disapproved by governing or regulatory bodies.

5.1.2 Surveillance Approaches

All survey data was collected online using SNAP surveys (Version 9), an advanced survey authoring tool and database management system and was hosted at the University of Pittsburgh Survey Research Program (www.survey.pitt.edu/MuayThai). Data for statistical analysis was exported directly from SNAP into SPSS v20. During a 1-year study, 195 completed surveys were submitted for analysis.

A primary aim during data collection was to assess the feasibility of conducting electronic surveillance by looking at contact, cooperation and response rates for the survey among a targeted 90 potential respondents on a randomly drawn from a series of fight events randomly selected over the study period. This resulted in 9 randomly selected events and then randomly drawing 10 fighters to target for recruitment. These fighters were then contacted via the follwing means:

1. *IN PERSON* where the principal investigator met personally with fighters prior to the event to explain the research project and to solicit participation as well as distribute consent forms that supplied the web link to access the survey. (n=30)
2. *DIRECT EMAIL* where the principal investigator obtained the emails of fighters from a fight event (reported on fight application) and subsequently emailed (within 1 week of event) the recruitment and consent to solicit participation. (n=30)
3. 2 *INDIRECT EMAIL* where the sanctioning body president (within 1 week of event) emailed the fighters to invite them to participate in the research endeavor and supplied the consent and web link on behalf of the principal investigator. (n=30)

5.1.3 Injury Definition

Fighters were asked whether or not painful injuries sustained during an actual fight occurred within the past 6 weeks or 6 months (2 recall periods). They were instructed to consider fight-specific injuries (in the ring), rather than those sustained during training prior to the fight. Additionally, they were asked to classify the primary injury (noting: *IF YOU SUSTAINED MULTIPLE INJURIES DURING THE FIGHT, WE ASK YOU THINK OF THE MOST SEVERE, SINGLE INJURY FOR THE FOLLOWING SERIES OF QUESTIONS. WE WILL REFER TO THIS AS THE PRIMARY INJURY*). An additional question was used to attempt to discover whether or not the injury sustained was truly a result of the fight or not. The respondent was asked to classify the primary injury as:

1. NEW INJURY (i.e., sustained during the fight)

2. AGGRAVATED INJURY (i.e., an injury sustained during fight training was aggravated during the fight)

3. RECURRENT INJURY (i.e., an injury sustained in the past that recurs periodically in training/fights)

5.1.4 Data Elements

In accordance with the International Collaborative Effort (ICE) on injury statistics, our surveillance included Important variables consistent with the ICE minimum basic dataset for injury monitoring in addition to elements associated with the injury incident.

- Date of injury incident
- Time of injury incident
- Location of injury incident
- Fighter class
    - Professional
    - Amateur
- Number of total fights experience
- Most recent fight occurrence
    - 6 weeks
    - 6 months
    - None within recall window
- Injury Severity
    - Self-defined using 4 levels
        - Level 0 - no bearing of fight
        - Level 1 - affected performance but did not influence outcome
        - Level 2 - interfered with fight performance but did not affect subsequent training
        - Level 3 - interfered with fight performance and delayed return to training or fighting
- Lost training time
- Nature of injury (e.g., sprain, strain, burn)

- Body part injured (e.g., head, back, arm)
- Mechanism of injury
    - Struck by, fall, collision, overexertion, lifting/pulling
- Injury incident report with open-ended description
- Initial treatment and by whom
- Fight classification
- Protective equipment worn
    - gloves only
    - gloves plus additional equipment such as headgear & shinpads
- Fighter weight class
- Fight outcome and open-ended description of how the fight ended
- Age
- Gender
- Race/Ethnicity

5.1.5 Data Analysis

Specific Aim #1**:** To develop and evaluate three surveillance approaches to identify MuayThai fight-related injuries. Three modes of recruitment were used with a single mode for survey administration (web).

Experimental Design:

The targeted sample will be recruited and surveyed using 3 distinct approaches:

- **In-person** recruitment conducted by the principal investigator at the fight event
- Primary/Direct **email** with invitation personalization (first name) sent from the personal email account of the principal investigator within 1 week of the event
- Secondary/Indirect **email** without personalization (generic) sent from the sanctioning body business email on behalf of the principal investigator within 1 week of the event

Data Analysis:

We will examine the contact, cooperation/response or refusal rates from each approach to assess the viability of each strategy. Eligible respondents will consist of all participants (fighters) at the selected event. Table 15 provides a visual framework for presenting these numbers later in the results section.

Table 15. Targeted Sample Rates

APPROACH	Eligible Respondents	Emails Sent/Letters Distributed	Emails Failed/Missed Letter	Surveys Started	Surveys Completed	Participation Rate
In Person	*30*	*27*	*3*	*16*	*13*	*48.%*
Direct email	*30*	*30*	*5*	*22*	*11*	*44%*
Indirect email	*30*	*30*	*0*	*15*	*8*	*27%*

*Example data provided for display. Actual data will be presented in RESULTS.

- Contact Rate will be calculated as the number of recruitment letters distributed using the in-person approach; total emails sent minus the number of email bounce backs (or failed delivery)/ number of emails sent
- Cooperation Rate/Response Rate will be calculated as the number of completed surveys returned/the total number of surveys sent minus any noncontacts
- Refusal Rate will be calculated as the number of eligible respondents declining participation/the total number of surveys sent minus the noncontacts

Within survey research, there are general modes of data collection, ranging from in-person to touchtone data entry. This may vary across study phases for recruitment and administration. The sample, however, generally drives which recruitment strategy and data collection method are optimal for maximizing response rates and minimizing costs. With this targeted convenience sample, we aimed to explore 3 recruitment approaches while maintaining consistency in administration to minimize potential mode effects, and assess which, if any, of the approaches garnered a higher response rate comparatively. Because no survey mode now dominates survey design (Dillman, 2011), mixed-mode and tailored design approaches are used based on population to eliminate potential response shortcomings of individual modes.

Specific Aim #2: To describe the frequency and severity of MuayThai fight-related injuries among a sample of professional and amateur fighters, and explore underlying demographic factors associated with the injury outcome.

Experimental Design & Analysis:

Initial frequency distributions will be used to summarize and present the descriptive data collected on the variables of interest, including: time, place, experience level, severity, nature and mechanism, age, gender, race and the fight outcome, weight class and equipment worn. Initial bivariate analyses will be done to assess the relationship between each of the potential covariates and the predictor as well as outcome variable (injury). A p value equaling .20 will be used as a cut-off for inclusion in later multiple regression modelling.

Specific Aim #3a: To determine if fight-related injury is related to years of fight experience.

Hypothesis: If fight-related injury is related to experience, then the fighters with less experience will have higher injury frequency and severity. Fighters who develop injuries when compared with those who did not have an injury will differ with respect to experience level (professional versus amateur); controlling for relevant covariates.

Experimental Design: Cases of fight-related injury for each fighter over the study period (2010) will be identified from the injury database. Data collected on these subjects include the number of total fights fought, and what the fighter's rank or status is, namely amateur or professional. For operationalizing experience, we will examine both with the binary (professional versus amateur) and the continuous (3 total fights) variables, as anecdotally, many fighters may never opt to fight professionally, therefore accumulating considerable experience, whereas others may jump to the pro ranks prematurely with relatively little time in the sport.

Data Analysis: A simple, univariate logistic regression model will be used to assess whether fight experience, both using a continuous variable (# total fights fought) and a dichotomous variable (amateur versus professional fighter) are predictive of fight-related injury (yes versus no) as the outcome variable.

Multivariate analysis will be done using multiple logistic regression to assess the relationship between fighter experience and injury. Individual level variables determined to be important in the bivariate analysis will be added to the model as well. Age will be forced into the model as well, due to the association with both the independent and dependent variables. Backwards regression will be used. After building a complete model, any variables excluding age will be removed from the model, and the model will be evaluated without them. If no change is apparent, they will be excluded from the final model (Hosmer & Lemeshow, 2000). Statistical analysis will be performed using SPSS v21.

Specific Aim #3b: To determine if fight-related injury is related to degree of protective equipment worn.Fighters who develop injuries when compared with those who did not have an injury will differ with respect to protective equipment worn; controlling for relevant covariates.

Hypothesis: If fight-related injury is related to protective equipment, then the fighters with less protection will have higher injury frequency and severity.

Experimental Design: Cases of fight-related injury for each fighter over the study period (2010) will be identified from the injury database. Data collected on these subjects from what protective equipment was worn during the fight. We will compare the level of protection as 1) gloves only -OR- 2) gloves + shin pads + headgear.

Data Analysis: A simple, univariate logistic regression model will be used to assess whether protective equipment worn, comparing two levels of protection (gloves versus glove/headgear/shinpads) is predictive of fight-related injury as the outcome variable.

Multivariate analysis will be done using multiple logistic regression to assess the relationship between the two levels of fighter protection and injury. Individual level variables determined to be important in the bivariate analysis will be added to the model as well. Age will be forced into the model as well, due to the association with both the independent and dependent variables. Backwards stepwise regression will be used. After building a complete model, any variables excluding age will be removed from the model, and the model will be evaluated without them. If no change is apparent, they will be excluded from the final model (Hosmer & Lemeshow, 2000). Statistical analysis will be performed using SPSS v21.

Specific Aim #3c: To determine if fight-related injury is related to pre-existing injury.

Fighters who develop injuries when compared with those who did not have an injury will differ with respect to having been previously injured leading up to the fight; controlling for relevant covariates.

Hypothesis: If fight-related injury is related to pre-existing injury, then the fighters with previous injuries leading up to a fight will have higher injury frequency and severity.

Experimental Design: Cases of fight-related injury for each fighter over the study period (2010) will be identified from the injury database. Data collected on these subjects from the database will include whether or not the fighter entered the fight with or without an injury. This will be garnered from 2 sources: 1) how many fights in the previous 6 months had they fought and sustained another injury, or 2) was the incidence of the fight-related injury in question entirely new, or a recurrence or aggravation of a previous injury.

Data Analysis: A simple, univariate logistic regression model will be used to assess whether a fighter entering his/her bout had incurred an injury prior to the start of the fight, and if this impacted the incidence of injury from the fight surveyed.

Multivariate analysis will be done using multiple logistic regression to assess the relationship between reporting a pre-existing injury when entering the bout and incurring a subsequent injury during the fight. Individual level variables determined to be important in the bivariate analysis will be added to the model as well. Age will be forced into the model as well, due to the association with both the independent and dependent variables. Backwards stepwise regression will be used. After building a complete model, any variables excluding age will be removed from the model, and the model will be evaluated without them. If no change is apparent, they will be excluded from the final model (Hosmer & Lemeshow, 2000). Statistical analysis will be performed using SPSS v21.

5.1.6 Power Calculations

Determinant Aims:

One goal of the proposed study is to test the null hypothesis that the proportion positive is identical in the two populations. The total sample size of the sample is fixed at 195. The injury rate within the population is 55.4% (108 injured, 87 noninjured fighters).

AIM 1: The proposed groups of 99 and 96 for the two exposures (pro vs. amateur) in the study will have power of 80% to detect a difference in proportions of 0.20 (specifically, 0.65 versus 0.45), when the criterion for significance (alpha) has been set at 0.05. The test is 2-tailed, which means that an effect in either direction will be interpreted.

AIM 2: The proposed groups of 110 and 85 for the two exposures (no protective equipment vs. protective equipment) in the study, based on 80% power, we will be able to detect a difference in proportions of 0.20 (specifically, 0.63 versus 0.43), when the criterion for significance (alpha) has been set at 0.05. The test is 2-tailed, which means that an effect in either direction will be interpreted.

AIM 3: The proposed groups of 140 and 53 for the two exposures (no previous injury vs. previous injury) in the study, based on 80% power, will be able to detect a difference in proportions of 0.22 (specifically, 0.64 versus 0.42), when the criterion for significance (alpha) has been set at 0.05. The test is 2-tailed, which means that an effect in either direction will be interpreted.

In summary, given 80% power, we would be able to detect the following effect sizes within the 3 aims:

a) pro versus amateur, **0.20**

b) no protective equipment versus protective equipment, **0.20**

c) no pre-existing injury versus pre-existing injury, **0.22**

It is assumed that this effect size is reasonable, in the sense that an effect of this magnitude could be anticipated in this field of research.

6.0 RESULTS

<u>AIM 1</u>: *To develop and evaluate three recruitment approaches for Muay Thai fight-related injuries in a participant-based survey approach to surveillance.*

The first primary aim was to examine the implications of three different recruitment approaches to identify Muay Thai fight-related injuries. Surveillance for Muay Thai injuries cannot utilize existing injury surveillance sources. Thus, it is important to identify and evaluate alternative approaches to monitor Muay Thai injury. Web surveys offer a standardized procedure and systematic approach so that every individual is asked the same questions in more or less the same way, therefore this method was chosen to administer the questionnaire to the sample. Three alternative methods for recruitment were developed and evaluated in this study. All approaches involved having participants complete a web-based survey on Muay Thai injury.

The three strategies are listed below:

<u>APPROACHES:</u>

1. **In-person** recruitment conducted by the principal investigator at a designated fight event
2. Primary/Direct **email** with invitation personalization (first name) sent from the personal email account of the principal investigator within 1 week after the event
3. Secondary/Indirect **email** without personalization (generic) sent from the sanctioning body business email on behalf of the principal investigator within 1 week after the event

The contact, cooperation, response and refusal rates were examined for each approach. Eligible respondents consisted of 30 randomly selected participants (fighters) at the targeted events, for an overall sub sample of 90 participants. Table 16 provides a visual framework of the results of this assessment.

Table 16. Contact, Coooperation, Participation and Refusal Rates by Survey Mode

Method	Eligible Subjects	Invited	Subjects Contacted	Surveys Started	Surveys Completed	Contact Rate	Cooperation Rate	Participation Rate	Refusal Rate
1. In Person	*30*	*27*	*27*	*12*	*8*	*90%*	*44%*	*30%*	*55%*
2. Direct email	*30*	*30*	*25*	*20*	*15*	*83%*	*80%*	*60%*	*20%*
3. Indirect email	*30*	*30*	*30*	*22*	*18*	*100%*	*73%*	*60%*	*27%*

Contact rates were calculated as the number of recruitment letters distributed using the in-person approach or the total emails (emails obtained via fight application) sent minus the number of email bounce backs (or failed delivery)/ number of emails sent. The highest rate achieved was 100%, with all 30 emails successfully delivered by the sanctioner on behalf of the investigator. The in-person approach yielded a 90% contact rate (27/30), while direct emails from the investigator yielded a slightly lower rate (83.3%; 25/30) due to 5 failed email invitations.

The cooperation rate was defined as the proportion of respondents who, having been contacted, agreed to participate. The lowest cooperation rate was among the in-person recruitment method, with only 12/27 (44%) of the eligible participants starting the survey. Rates were considerably higher among the emailed participants, yielding 80% (20/25) and 73% (22/30) in the respective direct and indirect approaches.

Response rates were defined as the number of completed surveys returned divided by the total number of surveys sent minus any non contacts. Both email approaches yielded the same rate of participation, with 60% finishing the survey. The in-person approach, however, yielded 1/2 that rate of return (30%).

Refusal rates were calculated as the number of eligible respondents declining participation divided by the total number of surveys sent minus the non contacts. Refusals, whether implicit or explicit included persons not logging into the survey, or persons logging into the survey and not completing any items. The highest refusal rate was 55.5% (15/27) persons from the in-person approach. Comparatively, the email approaches yielded considerably lower refusal rates 20% (direct email) and 26.7% (indirect email).

Table 17. Basic Characteristics of Survey Respondents by type of Surveillance Approach

Method	% Male	Race (% Caucasian)	Age (median)	% Heavier weight	% High experience	Protection (% padded)	Caliber (% pro)	% Pre-existing injury
1. In Person	*50*	*50*	*23.5*	*37*	*50*	*50*	*63*	*25*
2. Direct email	*67*	*80*	*25*	*67*	*54*	*40*	*67*	*33*
3. Indirect email	*67*	*100*	*28.5*	*61*	*33*	*62*	*33*	*40*

When comparing the basic characteristics of the 3 groups, there were slightly more Asian females at lighter weights who responded from the in-person approach (Table 17). A lower proportion of professionals reported when emailed by the sanctioning body, and given more amateurs participated, this group was slightly less experienced and more padded. However, no significant differences between the three groups was detected when comparing them on these individual characteristics.

Injury severity was also examined within a subsample of participants targeted based on the surveillance approach used. The majority of participants reported the two lowest levels (0-1), but in the indirect approach administered by the sanctioning body, there was a slightly higher proportion of fighters, though not statistically significant, that reported more severe injuries in the two highest levels (2-3) (Table 18).

Table 18. Injury Severity by Surveillance Approach (n=40*)

	In Person	Direct email	Indirect email	Total
LEVEL				
LEVEL 0 – Injury did not interfere with completion of fight (i.e., injury had no bearing on fight outcome)	5	10	11	26
LEVEL 1 – Injury did not interfere with completion of fight, but did affect performance during fight	2	2	0	4
LEVEL 2 – Injury did interfere with completion of fight, but did not affect subsequent training or fighting	0	0	2	2
LEVEL 3 – Injury did interfere with completion of fight, and did affect subsequent training or fighting	1	2	5	8
TOTAL	8	14	18	40

**Eligible and completed respondent subsample.*

AIM 2: *To describe the frequency and severity of Muay Thai fight-related injuries identified from the collective recruitment effort and explore underlying demographic factors associated with the injury outcomes.*

The second primary aim sought to describe the frequency and severity of Muay Thai fight-related injuries among a sample of professional and amateur fighters, and to explore the underlying demographic factors associated with the injury outcome. Surveillance of Muay thai fight injury was conducted from April 6, 2010 - January 17, 2011 using a logic driven, web-based survey that was emailed by the WKA sanctioning body administrative staff. The survey collected basic elements of the fight, and depending whether or not an injury was reported, additional injury-related questions were asked (e.g., nature, mechanism, body region, severity.) Complete surveys were collected from 195 respondents. Another 88 individuals partially completed the survey.

In the survey, fighters were also asked whether or not painful injuries were sustained during an actual fight within the past 6 weeks or 6 months (2 recall periods). They were instructed to consider fight-specific injuries (in the ring/location of injury), rather than those sustained during training prior to the fight. Additionally, they were asked to classify the primary injury (noting: *IF YOU SUSTAINED MULTIPLE INJURIES DURING THE FIGHT, WE ASK YOU TO THINK OF THE MOST SEVERE, SINGLE INJURY.*). If fighters reported more multiple fights resulting in injury, only the most recent fight within the recall period was the focus of the injury-related questions. An additional question was used to attempt to discover whether or not the injury sustained was truly a result of the fight or not. The respondent was asked to classify the primary injury as:

- NEW INJURY (i.e., sustained during the fight) -- n=74 (68.5%)
- AGGRAVATED INJURY (i.e., an injury sustained during fight training was aggravated during the fight) --n=12 (11.1%)
- RECURRENT INJURY (i.e., an injury sustained in the past that recurs periodically in training/fights) -- n=19 (2.8%)

6.1.1 Demographic Characteristics

Little information was obtained from the 88 partial respondents, as many terminated their participation early on in the instrument. Six of the respondents failed to consent, and 16 were screened out, due to inactivity as a fighter during the recall period. With 66 remaining partial responses, there were 35 that stopped the survey when asked about how many fights they had and to classify these as professional/amateur. Another 29 discontinued the survey when presented with the injury question. Finally, 2 more partialed out of the survey when asked whether the event was sanctioned or not. None of the partially completed survey respondents advanced far enough to answer the demographics questions.

Of the 195 participants with complete survey responses, 96 (49.2%) reported they were professional fighters and the remaining 99 (50.8%) reported they competed as amateur fighters. Fighters reported a range of fight experience from 1 to 111 total fights, with a mean of 15.83 (median=11.00). In terms of basic demographics, fighter's ages ranged from 18 to 47 years old, with a mean of 27.1 years (median=26). Males represented the majority of respondents 85.9% compared to females (13.8%). Most fighters reported their race/ethnicity as white (72.3%) followed by Asian (13.3%), Hispanic/Latino (4.6%), black (3.1%), mixed race (2.1%) and unreported (4.6%).

All fighters, regardless of injury status were then asked about the use of protective equipment and categorized as those using "gloves only" for protection or those in which gloves, plus additional protective equipment such as headgear and shinpads were worn (Table 19).

Table 19. Frequency Table of Fighter Protection among Injured and non-Injured

	Number	Percent
Gloves only	110	56.4
Gloves plus headgear/shinpads	85	43.6
Total	195	100

Fighters were also asked in which weight class the bout was contested at, ranging from Mini-Flyweight (105 pounds) to Super Heavyweight (209+ pounds). The majority of respondents fought at welterweight (147 lbs.) and higher (Table 20)

Table 20. Frequency Table of Fighter's Fight Weight (n=195)

	Number	Percent
Mini Flyweight - 105 lbs (47.727 kg.)	1	0.5
Flyweight - 112 lbs (50.802 kg.)	12	6.2
Bantamweight - 118 lbs (53.524 kg.)	16	8.2
Junior Featherweight - 122 lbs (55.338 kg.)	8	4.1
Featherweight - 126 lbs (57.153 kg.)	5	2.6
Junior Lightweight - 130 lbs (58.967 kg.)	8	4.1
Lightweight - 135 lbs (61.235 kg.)	17	8.8
Table 20 Continued (63.503 kg.)	7	3.6
Welterweight - 147 lbs (66.638 kg.)	26	13.4
Junior Middleweight - 154 lbs (69.853 kg.)	13	6.7
Middleweight - 160 lbs (71.575 kg.)	19	9.8
Super Middleweight - 168 lbs (76.363 kg.)	25	12.9
Light Heavyweight - 175 lbs (79.379 kg.)	11	5.7
Heavyweight - 190 lbs (86.183 kg.)	13	6.7
Super Heavyweight - 209 lbs. (95 kg.+)	13	6.7
Total	194	100

All respondents were asked about the outcome of their most recent fight, whether win, lose or draw. The percentage of losses by injury status was nearly the same, but slightly more injured fighters reported winning, while slightly more non injured fighters reported drawing with the opponent (Table 21).

Table 21. Fight Outcome by Injury Status

Fight Outcome	Non Injured (n; %)	Injured (n; %)	Total (n; %)
Win	32 (37%)	51 (47%)	78 (40%)
Loss	44 (50%)	52 (48%)	96 (49%)
Draw	16 (13%)	5 (5%)	21 (11%)
Total	87 (45%)	108 (55%)	195

6.1.2 Frequency of Injury

From these 195 respondents, 108 (55.4%) reported sustaining an injury during the fight, while the remaining 87 (44.6%) reported no incidence of injury. The overall injury rate was 11.25 injuries per 100 fight minutes. Fighters competing in the A-class category reported 8.4/100 and fighters competing in B-class bouts and lower reported a slightly higher rate of 12.8/100.

The fighters with injury were mostly professional (59%, n=64), did not wear protective padding other than gloves (65%, n=70), and did not enter the fight with a reported pre-existing injury (59%, n=64). When asked about the nature of the primary injury from the fight, respondents reported that the majority of these were bruises or contusions (Table 22).

Table 22. Frequency Table of Nature of Fight Injury

	Number	Percent
Bruise/Contusion	43	38.7
Cut/Laceration	16	14.4
Swelling/Inflammation	15	13.5
Fracture	14	12.6
Concussion (with pain)	6	5.4
Sprain	5	4.5
Strain	4	3.6
Overexertion	3	2.7
Total	108	100

The primary body region that was injured were the extremities in more than half of the reported fight injuries (Table 23). There were, comparatively, few reported head injuries.

Table 23. Frequency Table of Primary Body Region Injured

	Number	Percent
Extremities	65	58.6
Head/Neck	34	30.6
Trunk/Torso	12	10.8
Total	108	100

The primary cause or mechanism of the fight injuries was due to being "struck by" the opponent in more than 2/3 of the incidents (Table 24). Colliding with the opponent caused the next highest proportion of injuries. Those reporting injuries in the "other, specify" category described their injuries as a consequence of striking the opponent, versus being struck by the opponent.

Table 24. Frequency Table of Primary Cause or Mechanism of Injury

	Number	Percent
Struck by opponent	74	67.6
Collision with opponent	24	12.3
Lifting/Pulling	2	1.8
Overexertion	1	0.9
Other (struck opponent)	7	8.1
Total	108	100

6.1.3 Injury Severity

Of the 108 fighters who reported an injury, the self-reported severity levels reported ranged from Level 0 (injury did not interfere with completion of fight and had no bearing on outcome) to Level 4 (injury did interfere with fight and affected subsequent training or fighting) (Table 25).

Table 25. Frequency Table of Injury Severity among Respondents Injured in the Fight

LEVEL OF INJURY SEVERITY	Number	%
LEVEL 0 –Injury did not interfere with completion of fight (i.e., injury had no bearing on fight outcome)	72	66.7
LEVEL 1 – Injury did not interfere with completion of fight, but did affect performance during fight	7	3.6
LEVEL 2 – Injury did interfere with completion of fight, but did not affect subsequent training or fighting	7	3.6
LEVEL 3 – Injury did interfere with completion of fight, and did affect subsequent training or fighting	22	11.3
TOTAL	108	100

The bulk of the injuries to the fighters were self-reported relatively low in severity (67%). They did not perceive the injury to impact either completing the fight or the outcome (win, loss, draw).

Table 26. Injury Severity by Fight Outcome (n=107)

LEVEL OF INJURY SEVERITY	Win	Loss
LEVEL 0 –Injury did not interfere with completion of fight (i.e., injury had no bearing on fight outcome)	37	35
LEVEL 1 – Injury did not interfere with completion of fight, but did affect performance during fight	2	4
LEVEL 2 – Injury did interfere with completion of fight, but did not affect subsequent training or fighting	1	6
LEVEL 3 – Injury did interfere with completion of fight, and did affect subsequent training or fighting	5	17
TOTAL	45	62

When looking at the injury severity by the fight outcome, a significant difference was noted , in that the fighters that lost were more likely to report a higher injury severity (χ^2 p=.039; Fisher's exact p=.008). Both tests were run, as several cells had less than 5 expected counts.

Table 27. Mechanism of Injury by Reported Injury Severity (n=108)

	Struck by	Collision	Over-exertion	Lifting/ Pulling	Other	Total
LEVEL OF INJURY SEVERITY	%	%	%	%	%	%
LEVEL 0 – Injury did not interfere with completion of fight (i.e., injury had no bearing on fight outcome)	37.7	19.8	0	1.9	7.5	67.0
LEVEL 1 – Injury did not interfere with completion of fight, but did affect performance during fight	5.7	0	0	0	0	5.7

Table 27 Continued

LEVEL 2 – Injury did interfere with completion of fight, but did not affect subsequent training or fighting	5.7	0	0.9	0	0	6.6
LEVEL 3 – Injury did interfere with completion of fight, and did affect subsequent training or fighting	17.9	2.8	0	0	0	20.8
TOTAL	67.0	22.6	0.9	1.9	7.5	100

**Eligible and completed respondent subsample.*

Table 28. Nature of Fight Injury by by Reported Injury Severity (n=108)

Nature of Injury	Level 0	Level 1	Level 2	Level 3	Total
Bruise/Contusion	31.1	2.8	2.8	2.8	39.6
Cut/Laceration	7.5	0	0.9	4.7	13.2
Swelling/Inflammation	11.3	0.9	0	1.9	14.2
Fracture	5.7	0.9	0.9	4.7	12.3
Concussion (with pain)	0	0.9	0	4.7	5.7
Sprain	2.8	0	0.9	4.7	8.4
Strain	2.8	0	0	0.9	3.8
Overexertion	2.8	0	0	0	2.8
Total	64.0	5.5	5.5	24.4	100

6.1.4 Impact of Injury

Nearly 2/3 (66.7%) of all injured fighters reported that the injury did not interfere with the completion of the fight and was not a factor in the bout outcome (i.e., win, loss, draw). Of the fighters that reported a new incidence of injury, versus one classified as recurrent or aggravated, we followed up with several questions related to the severity and lost training time related to this new injury. 69 of the 74 injured fighters responded to this series of questions and when asked "HOW MUCH TRAINING TIME DID YOU MISS DUE TO THIS INJURY?", over 1/3 reported they missed no training time as a result of the injury incurred during the fight (Table 29).

Table 29. Frequency Table of Missed Training Time due to New Fight Injury

Time Lost from Training	Number	Percent
No time lost	36	33.6
1 day	17	15.7
2 days	10	9.3
3-7 days	15	13.9
1 week	6	5.6
2 week	11	10.2
> 2 weeks	12	11.1
Total	108	100

In addition to lost training time, fighters were queried as to whether or not they had to cancel or postpone a scheduled fight as a result of the injury. Thirty-six (33.3%) of the fighters declared they did not need to cancel a fight, as one was not scheduled. Of the remaining group, 60 of the injured fighters did not need to postpone or cancel (55.6%). Only 12 (11.1%) answered that the fight injury forced them to cancel an upcoming bout. As another potential consequence of the fight injury, fighters were asked whether they missed work time. The overwhelming majority (54; 79.4%) reported no lost work time. Of those needed to miss work, 5.9% missed 1 day; 7.4% missed 2 days; 2.9% missed 3-7 days and 4.4% were absent from work for more than 7 days.

6.1.5 Treatment of Injury

Participants were asked whether or not they required any initial treatment, and were asked to identify the type of treatment involved. Of those injured, 19 fighters reported that they needed no treatment at all. Thirty-five fighters injured reported that they only required self-treatment. The remaining 54 fighters sought a range of medical treatments, with most needing the RICE protocol. (Table 30).

Table 30. Frequency Table of the Type of Treatment Received for Injury in a Muay Thai Fight

	Number	Percent
No treatment required	19	17.6
Self-treated	35	32.4
Medical Treatment	*54*	*50.0*
Rest, Ice, Compression, Elevation (RICE)	*31*	*57.4*
Taping/Dressing	*6*	*11.1*
Sutures	*12*	*22.2*
Other (e.g., crutches, sling)	*5*	*9.3*
Total	108	100

Following up with the initial injury treatment, respondents were asked who actually performed the treatment received, if not self-treated. In most cases, the fight trainer (37.5%) initially treated the injury, followed by emergency medical services (23.4%), emergency departments (7.8%), outpatient care (14.1), inpatient care (7.8%) and physical therapy (9.4%).

Of those fighters injured, respondents were also asked to classify what rules the bout was fought under. Generally, A-Class bouts are full, professional Muay Thai rules allowing all techniques (punches, kicks, knees and elbows over 5, 3-minute rounds); A-class modified rules (no elbows permitted, *or* elbow pads worn over 5, 3-minute rounds); B-class (no elbows permitted, *or* elbow pads worn over 5, 2-minute rounds); C-class rules (no elbows permitted, *or* elbow pads worn over 3, 2-minute rounds) or novice level rules (no elbows permitted, *or* elbow pads worn over 3, 1.5-minute rounds). Table 31 shows a distribution of these classes among the injured fighter sample.

Table 31. Fight Classification among Injured (n=108)

	Number	Percent
A-Class (5x3 Full Muay Thai)	26	24.1
A-Class Modified Rules	6	5.5
B-Class	26	24.1
C-Class	42	38.9
Novice/Interclub	8	7.4
Total	108	100

<u>AIM 3</u>: To study the determinants of Muay Thai fight-related injury in the collective surveillance sample and identify if:

A. *fight-related injury is related to fight experience.*

B. *fight-related injury is related to degree of protective equipment worn by participants.*

C. *fight-related injury is related to pre-existing injury.*

Initial bivariate analyses were run to assess the relationship between several fight-related covariates and injury in this sample. The variables addressed here include those with a p-value equalling .20, which was used as a cut-off for inclusion in later multiple regression modelling addressed in specific aim #4. The variables identified in this process included the fight experience of the fighter (both as a continuous variable and as a dichotomous variable using a median split within the sample (median 15 fights)); the fighter level (professional or amateur); the protective equipment worn (gloves or gloves + shinpads + headgear); and prevalence of a pre-existing injury (yes or no) prior to the most recent fight. Both age and weight were also found to be significant in the bivariate analysis, and would be used for adjustments in subsequent models. The results of these assessments are addressed below in Table 32. Variables that were not found to be relevant included sex (p=.221) and the fight outcome (p=.411). Sex was then forced into the models as a potential covariate as this is often associated with differences in injury outcomes (Ristolainen, 2009), and it was very close to the .20 significance threshold.

Table 32. Bivariate Regression Analysis of the relation between injury and several fight-related variables (n=195)

	B	SE	Wald	df	P-value	OR	95% CI
Fight Status (professional vs. amateur)	.916	.296	9.564	1	.002	2.5	1.399-4.468
Protective equipment (none vs. all)	-.772	.295	6.863	1	.009	.462	.259-.823
Previous injury (yes vs. no)	.590	.310	3.635	1	.057	1.805	.984-3.311
Fight experience (per fight)	.031	.011	7.447	1	.006	1.031	1.009-1.056
Fight experience (>15 fights)	.986	.310	10.118	1	.001	2.681	1.460-4.924
Fight weight	-.080	.035	5.070	1	.024	.923	.861-.990
Age (>26)	-.109	.028	14.987	1	.000	.896	.848-.947

6.1.6 Fight Experience and Injury

A key question entering the study was if fight-related injury was related to fight experience, with the hypothesis that fighters with less experience would have higher injury frequency and severity. A simple, univariate logistic regression model was used to assess whether fight experience, both using a dichotomous variable (fights under or over 15) continuous variable (# total fights fought) and a third measure of experience (amateur versus professional fighter) were predictive of fight-related injury (yes versus no) as the outcome variable. (Table 33). Tables 33-38 illustrate the multivariate analyses done to assess the relationship between fighter experience and injury. Individual level variables determined to be important in the bivariate analysis were added to the model. Age was forced into the model as well, due to the association with both the independent and dependent variables. The backwards stepwise regression procedure was followed in the model. After building a complete model, each variable excluding age was removed from the model, and the model was evaluated without them. If no change was apparent, the variable was excluded from the final model (Hosmer & Lemeshow, 2000).

In the first assessment, the model was run, using fight experience (high versus low) by taking the median split (16 fights) from the total number of fights fought, reported by the participants (Table 33). Fight experience, sex and age were all significant in the model. Participants with high levels of fight experience odds were 3.6 times higher for a fight-related injury than those with low levels of fight experience.

Table 33. Regression Analysis of the relation between injury and fight experience (dichotomous), age, sex and weight adjusted (n=195)

	B	SE	Wald	df	P-value	OR	95% CI
Fight Experience (high versus low)	1.278	.347	13.569	1	.000	3.591	1.819-7.088
Age (>26)	-1.190	.329	13.087	1	.000	.304	.160-.580
Sex (Female v. Male)	1.056	.490	4.648	1	.031	2.875	1.101-7.509

Variables entered on STEP 1: Fight experience (>15), Weight, Age (>26), Sex (Female v. Male)

In the second assessment, a logistic regression model was run (Table 34), using fight experience or total number of fights fought, as a continuous variable. In the final model, weight class was not significant and only age, sex and number of fights remained in the model. In these results, each additional fight increased the chance of reporting a fight-related injury by 4.5%.

Table 34. Regression Analysis of the relation between injury and fight experience (continuous), age & sex adjusted (n=195)

	B	SE	Wald	df	P-value	OR	95% CI
Fight Experience (continuous)	.044	.013	11.873	1	.001	1.045	1.019-1.072
Age (>26)	-1.256	.330	14.444	1	.000	.285	.149-.544
Sex (Female v. Male)	1.041	.483	4.636	1	.031	2.831	1.098-7.301

Variables entered on STEP 1: Fight experience (CV), Weight, Age (>26), Sex (Female v. Male)

Lastly, the analysis examined if the classification of the fighter (amateur vs. professional) was related to injury (Table 35). In this assessment, weight dropped out of the model, and only age and fight status remained in the final model. Professional fighters were 3 times more likely to report an injury compared to amateur fighters.

Table 35. Regression Analysis of the relation between injury and fight status, age & sex adjusted (n=195)

	B	SE	Wald	df	P-value	OR	95% CI
Fight Status* (professional vs. amateur)	1.104	.321	11.807	1	.001	3.015	1.607-5.658
Age (>26)	-1.059	.318	11.079	1	.001	.347	.186-.647
Sex (Female v. Male)	.945	.478	3.910	1	.048	2.578	1.008-6.559

**Injury frequency was higher among pros compared to amateurs. Variables entered on STEP 1: Pro v. Amateur, Weight, Age (>26), Sex (Female v. Male)*

Table 36. Regression Analysis of the relation between injury and experience, protection level & pre-existing injury, age, sex & weight adjusted (n=190)

	B	SE	Wald	df	P-value	OR	95% CI
Fight experience (>15)	.998	.403	6.149	1	.013	2.714	1.233-5.973
Pro v. Amateur	.690	.525	1.724	1	.189	1.994	.712-5.583
Protection Level	.130	.521	.062	1	.803	1.139	.410-3.161
Preexisting Injury	.619	.346	3.196	1	.074	1.857	.942-3.659
Weight	-.413	.358	1.333	1	.248	.661	.328-1.334
Age (>26)	-1.178	.340	12.036	1	.001	.308	.158-.599
Sex (Female v. Male)	1.103	.533	4.283	1	.039	3.013	1.060-8.561
CONSTANT	-1.106	.833	1.763	1	.184	.331	
Fight experience (>15)	.984	.399	6.094	1	.014	2.676	1.225-5.846
Pro v. Amateur	.597	.370	2.604	1	.107	1.817	.880-3.752
Preexisting Injury	.622	.346	3.234	1	.072	1.863	.946-3.669
Weight	-.409	.358	1.307	1	.253	.664	.330-1.339
Age (>26)	-1.170	.338	11.996	1	.001	.310	.160-.602
Sex (Female v. Male)	1.119	.529	4.471	1	.034	3.061	1.085-8.637
CONSTANT	-1.025	.766	1.789	1	.181	.359	

Table 36 Continued

Fight experience (>15)	.938	.394	5.657	1	.017	2.555	1.179-5.534
Pro v. Amateur	.652	.366	3.183	1	.074	1.920	.938-3.932
Preexisting Injury	.622	.345	3.257	1	.071	1.863	.948-3.663
Age (>26)	-1.195	.336	12.649	1	.000	.303	.157-.585
Sex (Female v. Male)	1.268	.511	6.150	1	.013	3.555	1.305-9.688
CONSTANT	-1.463	.665	4.836	1	.028	.232	
Fight experience (>15)	1.260	.351	12.871	1	.000	3.524	1.771-7.012
Preexisting Injury	.644	.342	3.535	1	.060	1.904	.973-3.725
Age (>26)	-1.207	.333	13.140	1	.000	.299	.156-.575
Sex (Female v. Male)	1.222	.507	5.805	1	.016	3.394	1.256-9.170
CONSTANT	-1.221	.645	3.588	1	.058	.295	
Fight experience (>15)	1.278	.347	13.569	1	.000	3.591	1.819-7.088
Age (>26)	-1.190	.329	13.087	1	.000	.304	.160-.580
Sex (Female v. Male)	1.056	.490	4.648	1	.031	2.875	1.101-7.509
CONSTANT	-.826	.598	1.908	1	.167	.438	

Variables entered on STEP 1: Fight experience (>15), Protection Level, Pro v. Amateur, Preexisting Injury, Age (>26), Weight

To assess the relationship between fight experience, fighter protection, pre-existing injury and fight-related injury, multivariate analysis was performed using backwards stepwise regression starting with a complete model, removing any variables (excluding age) were removed and the model was evaluated without them. The first model used fight experience as a dichotomous variable (>15) in Table 36. The results indicate that higher fight experience, when compared with lower experience resulted in an increase in likelihood of injury (OR=3.6, p=.000) when adjusting for age and weight. Neither protection level nor pre-existing injury were found to be significant and both were removed from the model.

Replacing the fight experience level (>15) with total fights reported as a continuous variable (CV), and running the same model showed a small, but significant result. Compared to fighters with fewer fights, those with more were 1.05 times more likely to sustain a fight-related injury (p=.001) when adjusting for age. (Table 37)

Table 37. Regression Analysis of the relation between injury and experience, protection level & pre-existing injury, age, sex & weight adjusted (n=190)

	B	SE	Wald	df	P-value	OR	95% CI
Fight experience (CV)	.034	.015	5.395	1	.020	1.035	1.005-1.065
Pro v. Amateur	.686	.522	1.726	1	.189	1.986	.714-5.526
Protection Level	.147	.518	.080	1	.777	1.158	.419-3.198
Preexisting Injury	.617	.347	3.167	1	.075	1.854	.939-3.659
Weight	-.405	.358	1.278	1	.258	.667	.331-1.346
Age (>26)	-1.229	.343	12.846	1	.000	.293	.150-.573
Sex (Female v. Male)	1.079	.528	4.183	1	.041	2.942	1.046-8.272
CONSTANT	-1.208	.839	2.073	1	.150	.299	
Fight experience (CV)	.033	.014	5.350	1	.021	1.034	1.005-1.063
Pro v. Amateur	.583	.374	2.430	1	.119	1.792	.861-3.731
Preexisting Injury	.622	.346	3.219	1	.073	1.862	.944-3.672
Weight	-.399	.357	1.247	1	.264	.671	.333-1.351
Age (>26)	-1.218	.340	12.802	1	.000	.296	.152-.577
Sex (Female v. Male)	1.098	.524	4.393	1	.036	2.997	1.074-8.366
CONSTANT	-1.115	.772	2.086	1	.149	.328	
Fight experience (CV)	.032	.014	5.029	1	.025	1.033	1.004-1.062
Pro v. Amateur	.635	.371	2.937	1	.087	1.887	.913-3.902
Preexisting Injury	.623	.345	3.256	1	.071	1.865	.948-3.670
Age (>26)	-1.245	.339	13.519	1	.000	.288	.148-.559
Sex (Female v. Male)	1.252	.505	6.139	1	.013	3.496	1.299-9.410

Table 37 Continued

CONSTANT	-1.547	.671	5.320	1	.021	.213	
Fight experience (CV)	.044	.013	11.526	1	.001	1.045	1.019-1.072
Preexisting Injury	.652	.343	3.615	1	.057	1.920	.980-3.761
Age (>26)	-1.280	.335	14.617	1	.000	.278	.144-.536
Sex (Female v. Male)	1.208	.500	5.846	1	.016	3.348	1.257-8.918
CONSTANT	-1.367	.657	4.324	1	.038	.255	
Fight experience (CV)	.044	.013	11.873	1	.001	1.045	1.019-1.072
Age (>26)	-1.256	.330	14.444	1	.000	.285	.149-.544
Sex (Female v. Male)	1.041	.483	4.636	1	.031	2.831	1.098-7.301
CONSTANT	-.966	.612	2.495	1	.114	.381	

Variables entered on STEP 1: Fight experience (CV), Pro v. Amateur, Protection Level, Preexisting Injury, Weight, Age (>26), Sex (Female v. Male)

The issue of statistical interaction potentially arising between two predictor variables (age and total fight experience) was a concern. To see if the prior model should include this interaction, and whether or not this culminates in a conditional effect, that is, the effect of one predictor is conditional on the value of the other, the interaction term (age x fight experience) was put into the model for evaluation. The results shown in Table 6.1.24 indicate the interaction was not significant (p=.619), and thus, the effect of experience on injury does not vary significantly by age.

Table 38. Age Group x Fight Experience, Percent Injured (n=192)

		Age
Fight Experience	< 26 years	≧ 26 years
< 16 fights	56.7%	35.0%
≧ 16 fights	86.1%	56.0%

Table 39. Regression Analysis of the relation between injury and experience, protection level, pre-existing injury, age x experience, age, sex & weight adjusted (n=190)

	B	SE	Wald	df	P-value	OR	95% CI
Fight experience (>15)	1.218	.601	4.099	1	.043	3.379	1.040-10.983
Protection Level	.135	.520	.067	1	.795	1.144	.413-3.170
Pro v. Amateur	.681	.525	1.683	1	.195	1.976	.706-5.532
Preexisting Injury	.624	.346	3.248	1	.072	1.866	.947-3.676
Weight	-.413	.358	1.331	1	.249	.662	.328-1.335
Age (>26)	-1.053	.418	6.359	1	.012	.349	.154-.791
Sex (Female v. Male)	1.048	.540	3.760	1	.052	2.852	.989-8.223
Age x Experience (>15)	-.367	.731	.253	1	.615	.693	.165-2.900
CONSTANT	-1.102	.831	1.757	1	.185	.332	
Fight experience (>15)	1.201	.598	4.034	1	.045	3.322	1.029-10.723
Pro v. Amateur	.585	.370	2.494	1	.114	1.794	.869-3.707
Preexisting Injury	.627	.346	3.287	1	.070	1.872	.950-3.686
Weight	-.408	.357	1.304	1	.254	.665	.330-1.340
Sex (Female v. Male)	-1.046	.417	6.304	1	.012	.351	.155-.795
Age (>26)	1.065	.537	3.937	1	.047	2.901	1.013-8.305
Age x Experience (>15)	-.363	.730	.248	1	.619	.695	.166-2.910
CONSTANT	-1.017	.764	1.773	1	.183	.362	
Fight experience (>15)	.984	.399	6.094	1	.014	2.676	1.225-5.846
Pro v. Amateur	.597	.370	2.604	1	.107	1.817	.880-3.752
Preexisting Injury	.622	.346	3.234	1	.072	1.863	.946-3.669
Weight	-.409	.358	1.307	1	.253	.664	.330-1.339
Age (>26)	-1.170	.338	11.996	1	.001	.310	.160-.602
Sex (Female v. Male)	1.119	.529	4.471	1	.034	3.061	1.085-8.637
CONSTANT	-1.025	.766	1.789	1	.181	.359	
Fight experience (>15)	.938	.394	5.657	1	.017	2.555	1.179-5.534

Table 39 Continued

Pro v. Amateur	.652	.366	3.183	1	.074	1.920	.938-3.932
Preexisting Injury	.622	.345	3.257	1	.071	1.863	.948-3.663
Age (>26)	-1.195	.336	12.649	1	.000	.303	.157-.585
Sex (Female v. Male)	1.268	.511	6.150	1	.013	3.555	1.305-9.688
CONSTANT	-1.463	.665	4.836	1	.028	.232	
Fight experience (>15)	1.260	.351	12.871	1	.000	3.524	1.771-7.012
Preexisting Injury	.644	.342	3.535	1	.060	1.904	.973-3.725
Age (>26)	-1.207	.333	13.140	1	.000	.299	.156-.575
Sex (Female v. Male)	1.222	.507	5.805	1	.016	3.394	1.256-9.170
CONSTANT	-1.221	.645	3.588	1	.058	.295	
Fighter experience (>15)	1.278	.347	13.569	1	.000	3.591	1.819-7.088
Age (>26)	-1.190	.329	13.087	1	.000	.304	.160-.580
Sex (Female v. Male)	1.056	.490	4.648	1	.031	2.875	1.101-7.509
CONSTANT	-.826	.598	1.908	1	.167	.438	

Variables entered on STEP 1: Fight experience (>15), Protection Level, Pro v. Amateur, Preexisting Injury, Age (>26), Weight, Age x Experience

6.1.7 Protective Equipment and Injury

A critical question in Muay Thai involves the role of protective equipment in the prevention of injury. Specific aim 3b looked to determine if fight-related injury is related to degree of protective equipment worn. The hypothesis was that those fighters who develop injuries when compared with those who did not have an injury will differ with respect to protective equipment worn; controlling for relevant covariates. In the analysis, the level of protection was classified as 1) gloves only -OR- 2) gloves + shin pads + headgear. A simple, univariate logistic regression model was used to assess whether protective equipment worn, comparing two levels of protection (gloves versus glove/headgear/shinpads) predicted fight-related injury as the outcome variable.

In the final model, age, sex and the level of protection remained significant (Table 40). In this result, higher levels of protection were associated with less frequent reports of injury. In other words, it appears that wearing additional padding is protective for injury.

Table 40. Regression Analysis of the relation between injury and protection level, age & sex adjusted (n=195)

	B	SE	Wald	df	P-value	OR	95% CI
Protection Level	-.867	.318	7.424	1	.006	.420	.225-.784
Age (>26)	-.988	.312	10.054	1	.002	.372	.202-.686
Sex (Female v. Male)	.939	.475	3.913	1	.048	2.558	1.009-6.488

Variables entered on STEP 1: Protection Level, Age (>26), Weight, Sex (Female v. Male)

To assess the relationship between fighter protection, fighter experience, pre-existing injury and fight-related injury, multivariate analysis was performed using backwards stepwise regression starting with a complete model. The model used fight experience as a dichotomous variable (>15) in Table 41. The results indicate that when adjusting for age and weight, and including the fight experience and preexisting injury, protection level was not found to be significant and removed from the model.

Table 41. Regression Analysis of the relation between injury and experience, protection level & pre-existing injury, age, sex & weight adjusted (n=190)

	B	SE	Wald	df	P-value	OR	95% CI
Protection Level	.130	.521	.062	1	.803	1.139	.410-3.161
Fight experience (>15)	.998	.403	6.149	1	.013	2.714	1.233-5.973
Pro v. Amateur	.690	.525	1.724	1	.189	1.994	.712-5.583

Table 41 Continued

Preexisting Injury	.619	.346	3.196	1	.074	1.857	.942-3.659
Weight	-.413	.358	1.333	1	.248	.661	.328-1.334
Age (>26)	-1.178	.340	12.036	1	.001	.308	.158-.599
Sex (Female v. Male)	1.103	.533	4.283	1	.039	3.013	1.060-8.561
CONSTANT	-1.106	.833	1.763	1	.184	.331	
Fight experience (>15)	.984	.399	6.094	1	.014	2.676	1.225-5.846
Pro v. Amateur	.597	.370	2.604	1	.107	1.817	.880-3.752
Preexisting Injury	.622	.346	3.234	1	.072	1.863	.946-3.669
Weight	-.409	.358	1.307	1	.253	.664	.330-1.339
Age (>26)	-1.170	.338	11.996	1	.001	.310	.160-.602
Sex (Female v. Male)	1.119	.529	4.471	1	.034	3.061	1.085-8.637
CONSTANT	-1.025	.766	1.789	1	.181	.359	
Fight experience (>15)	.938	.394	5.657	1	.017	2.555	1.179-5.534
Pro v. Amateur	.652	.366	3.183	1	.074	1.920	.938-3.932
Preexisting Injury	.622	.345	3.257	1	.071	1.863	.948-3.663
Age (>26)	-1.195	.336	12.649	1	.000	.303	.157-.585
Sex (Female v. Male)	1.268	.511	6.150	1	.013	3.555	1.305-9.688
CONSTANT	-1.463	.665	4.836	1	.028	.232	
Fight experience (>15)	1.260	.351	12.871	1	.000	3.524	1.771-7.012
Preexisting Injury	.644	.342	3.535	1	.060	1.904	.973-3.725
Age (>26)	-1.207	.333	13.140	1	.000	.299	.156-.575
Sex (Female v. Male)	1.222	.507	5.805	1	.016	3.394	1.256-9.170
CONSTANT	-1.221	.645	3.588	1	.058	.295	
Fight experience (>15)	1.278	.347	13.569	1	.000	3.591	1.819-7.088
Age (>26)	-1.190	.329	13.087	1	.000	.304	.160-.580
Sex (Female v. Male)	1.056	.490	4.648	1	.031	2.875	1.101-7.509
CONSTANT	-.826	.598	1.908	1	.167	.438	

Variables entered on STEP 1: Fight experience (>15), Protection Level, Pro v. Amateur, Preexisting Injury, Age (>26), Weight, Sex (Female v. Male)

6.1.8 Previous Injury

As much of the injury literature has indicated that history of injury is a strong factor related to subsequent injury, specific aim 3c sought to determine if fight-related injury was related to pre-existing injury. It was hypothesized that fighters who develop injuries when compared with those who did not have an injury differ with respect to having been previously injured. A simple, univariate logistic regression model was used to evaluate whether if an injury incurred prior to the start of the fight impacted the incidence of injury from the fight surveyed. In the final model, pre existing injury was not significant, nor was sex, leaving only age as the significant predictor. (Table 42).

Table 42. Regression Analysis of the relation between injury and pre-existing injury, age & sex adjusted (n=191)

	B	SE	Wald	df	P-value	OR	95% CI
Previous Injury	.683	.329	4.324	1	.038	1.98	1.040-3.811
Age (>26)	-1.025	.310	10.956	1	.001	.359	.196-.658

Variable(s) entered on step 1: pre existing injury, age, weight, sex

To assess the relationship between preexisting injury, fighter protection, fighter experience and fight-related injury, multivariate analysis was performed using backwards stepwise regression starting with a complete model. The model used fight experience as a dichotomous variable (>15) in Table 43. The results indicate that when adjusting for age, weight and sex, including the fight experience, fighter status and protection level, pre existing injury was found to be significant with an odds ratio of nearly 2 times that of fighters who had not declared an injury within 6-months of the fight.

Table 43. Regression Analysis of the relation between injury and experience, protection level & pre-existing injury, age, sex & weight adjusted (n=190)

	B	SE	Wald	df	P-value	OR	95% CI
Preexisting Injury	.619	.346	3.196	1	.074	1.857	.942-3.659
Fight experience (>15)	.130	.521	.062	1	.803	1.139	.410-3.161
Pro v. Amateur	.998	.403	6.149	1	.013	2.714	1.233-5.973
Protection Level	.690	.525	1.724	1	.189	1.994	.712-5.583
Weight	-.413	.358	1.333	1	.248	.661	.328-1.334
Age (>26)	-1.178	.340	12.036	1	.001	.308	.158-.599
Sex (Female v. Male)	1.103	.533	4.283	1	.039	3.013	1.060-8.561
CONSTANT	-1.106	.833	1.763	1	.184	.331	
Preexisting Injury	.622	.346	3.234	1	.072	1.863	.946-3.669
Fight experience (>15)	.984	.399	6.094	1	.014	2.676	1.225-5.846
Pro v. Amateur	.597	.370	2.604	1	.107	1.817	.880-3.752
Weight	-.409	.358	1.307	1	.253	.664	.330-1.339
Age (>26)	-1.170	.338	11.996	1	.001	.310	.160-.602
Sex (Female v. Male)	1.119	.529	4.471	1	.034	3.061	1.085-8.637
CONSTANT	-1.025	.766	1.789	1	.181	.359	

Variables entered on STEP 1: Fight experience (>15), Protection Level, Pro v. Amateur, Preexisting Injury, Age (>26), Weight, Sex (Female v. Male)

7.0 DISCUSSION

Combat sports are, by design, considered more dangerous compared to other sports. However, the injury history and injury patterns associated with emerging combat sports such as Muay Thai are not fully known. Profiling the issue of injury in Muay Thai fighting by establishing an epidemiology-based surveillance is the initial step in order to truly begin to research and identify risk and protective factors within this sport. The overall goal of this dissertation project was to investigate a surveillance method for Muay Thai fight-related injuries, and to collect information regarding the magnitude and scope of the injury problem in the sport of Muay Thai.

Establishing a surveillance mechanism to target injuries from Muay Thai fights is a difficult process. Current surveillance systems are not a viable option because these systems miss many injuries to Muay Thai fighters. This means that a surveillance system which actively targets injuries to Muay Thai fighters must be built. For this study, a web-based survey was selected as the primary surveillance method to collect information on injuries at the fighter-level.

Web-based surveys have increased in prominence since emerging more than a decade ago (Couper, 2000). Data that had once been collected by other survey modes is now being collected with Web surveys (Dillman and Bowker, 2001). No other method of collecting survey data offers so much potential for so little cost as Web surveys (Dillman, 2000). Zanutto (2001) described many of the reasons for the popularity with Web surveys describing advantages such as a faster response rate; easier to send reminders to participants; easier to process data, since responses could be downloaded to a data analysis package; dynamic error checking capability; the ability to make complex skip pattern questions easier to follow; the inclusion of instructions for selected questions; and, the use of drop-down boxes. These are possibilities that cannot be included in paper surveys.

The choice to use the web-based survey among Muay Thai fighters was partly an economical consideration, but also included deliberation over the many alternative techniques and other issues. Web-based surveys have a number of benefits over conventional paper or face-to-face methods, allowing a further reach than postal or phone surveys or direct interviews. Since we were sampling from a widespread pool of fighters, maximizing participation was considered best accomplished via a web-based survey among the fighters. The data were captured directly in electronic format, making analysis faster and cheaper, providing more data to be collected than with conventional mailed paper questionnaires, attempting to conduct in-person interviews, or going to healthcare institutions that may warehouse records for review, such as emergency departments. Additional anecdotes from fighters, coaches and trainers are that the Internet is a frequently used tool for viewing fights (YouTube), interacting with the fight community via social media (FaceBook, Twitter) and registering with sanctioning bodies (WKA, TBA, IKF) in order to locate fight news, events, or even be ranked as a fighter.

Several recruitment approaches were developed and tested to elicit participation in the web-based survey. One method was to attend the fight event and actively distribute the recruitment letters to the fighters to explain the aims and purpose of the study. As the investigator is actively involved in the sport in multiple capacities (former fighter, coach and official), this was seen as a benefit to have direct contact with eligible respondents in order to increase cooperation by fielding questions or concerns. As the Internet has become a popular recruitment tool for potential research subjects, investigators have increasingly used list-based email approaches for participation. Therefore, this study also investigated the viability and participation rates associated with 2 other electronic-based approaches for recruitment. A second method was to send email to participants directly, asking for participation in the research study. Email addresses were obtained from the sanctioning body overseeing the fight, and sent by the investigator. The third method established was to have the sanctioning body distribute email on behalf of the investigator, encouraging eligible respondents to consider participating in the research study.

The timing of the in-person approach to recruitment produced interesting outcomes. While direct contact rates were high in-person (90%), approaching fighters directly before or immediately after the fight yielded poorer cooperation (44%). Perhaps fighters approached within a few hours before the fight are preoccupied with the upcoming bout, and while informed of the study, were distracted. Describing the nature of an injury study prior to the fight may also antagonize the fighter resulting in loss of interest. Similarly, fighters recruited immediately after fighting may be less inclined to participate for a variety of reasons. A winning fighter often shifts to celebration mode, surrounded by fans, friends and family, serving to draw attention from recruitment efforts. Conversely, losing fighters tend to commiserate and retreat from public interaction, discouraged by the fight result, conceivably affecting their willingness to do an injury survey.

In addition, while many fighters agreed to participate using this approach, they were handed an additional burden of having to use a paper-based link and type this into a web browser in order to access the survey. This additional step may have discouraged participants, and entering the URL incorrectly may have served as a deterrent.

In the second email approach involving an email sent by the investigator, eligible respondents were contacted 1 week after the fight. In the third approach, eligible respondents were contacted 1 week after the fight by the sanctioning body on behalf of the investigator.

Both of these groups were more likely to cooperate (83% and 100% respectively) and complete the survey, doubling the response rates (60%) when compared with the in-person recruitment approach. Two considerations for this increase are that allowing fighters a longer window for contact after the fight eliminated distractions, coupled with a clickable survey link to reduce respondent burden.

As with any recruitment effort, non-response bias may affect the study result where individuals unwilling or unable to participate may have different fight experiences than those who did not participate. Nonresponse rates among the 3 approaches was 55%, 20% and 26%, in person, direct email, indirect email, respectively. Both electronic approaches yielded less than 1/2 the non-response compared to the in person approach. It is possible that the 41 respondents differed in some meaningful way from the 49 nonrespondents. For example, if the fighter did not have an injury to report, then they may not see the need to participate in an injury survey. Also, those severely injured may refuse to participate for fear of disclosing this to the investigators or sanctioning body. Alternatively, those with a severe injury may have been unable to complete due to the extent of the injury, such as concussion.

This study did not conduct nonresponse followup, so another way to test for nonresponse bias was to obtain information known from all potential participants for comparison to the values that prevail in the subgroup of those who answered. This information was available publicly, as the bout details were distributed at the event and posted online to officially record results. On aggregate, the 41 respondents included 26 males (63%) compared to 34 male nonrespondents (70%). When comparing the fighters' status the respondents were 51% professional, with slightly fewer (45%) professional fighters among the nonresponders. Neither age nor ethnicity was obtainable from either the fight card or web results, so it remains unclear how similar the two groups are demographically on those measures. When stratifying by the surveillance approach, there are some differences to highlight, particularly within the in-person approach as higher proportion of females responded when approached in person depicted in Table 44.

Table 44. Comparison of Respondents (n=41) and Nonrespondents (n=49) across the 3 surveillance approaches

	In-person		PI email		Indirect email	
Responded	YES	NO	YES	NO	YES	NO
Gender	50% female ; 50% pro	80% male	66% male	80% male	66% male	80% male
Fighter Status	63% pro		67% pro		43% pro	

Generally speaking, the lower the response rate, the greater the likelihood of a nonresponse bias in play. Comparing these response rates, nonresponse bias would appear to be more likely an issue among those fighters recruited in-person versus those emailed.

Forty-one surveys were submitted among the 90 targeted eligible respondents. Contact rates were high across the three recruitment approaches (90%, 83%, 100%, respectively), and cooperation was lowest (44%) among those recruited in person. Of the group starting the survey recruited in person, 33% dropped out, while 67% completed the survey. Eight percent of those contacted via direct email began the survey, resulting in 75% of them completing the survey and 25% stopping. Among those contacted via email indirectly, cooperation was slightly lower than direct email (73%), but 81% that began the survey completed it, with 19% not filling out the entire instrument. It did not appear that survey length was a big issue as the average time to completion was 16 minutes in 195 submissions.

During the survey administration to the convenience sample, there were 66 partial respondents. Two-hundred twenty individuals began the survey, with 154 completing the entire instrument.

It should be noted that participants within the convenience sample had potentially longer recall periods of up to 6-months for the most recent fight, compared to the targeted sample that was recruited within a week of fighting. Targeted respondents reported a higher injury rate when compared to the convenience sample (73% vs. 44%). They reported similar proportions when comparing fighter rank (50% pro vs. 50% pro), protection level (50% none vs. 58%), previous injury (34% yes vs. 35%), fight experience (56% low vs. 62% low), age (56% younger vs. 47%), weight (41% lighter vs. 32%) and fight outcome (39% won vs. 40%).

The participants that stopped taking the survey are of interest as 29 dropped out when presented with the injury question, or what the case definition of injury was for the study. While the exact reason for breaking off here is not known, it is plausible that respondents did not have a reportable injury and selected out, or, there may have been definitional issues on this question and potential respondents did not understand the injury case definition.

An additional 35 respondents stopped taking the survey at the questions asking to classify the level of the fight. This question does need refinement, as the class system, while widely used in Europe, is less commonly used in North America. The description provided did define A, B, C and novice classes for the respondent, but it is possible that a respondent may have been unfamiliar with these divisions, and was confused on how to respond and stopped for the remainder of the instrument.

A recruitment effort to identify Muay Thai fight-related injuries might be more successful if the presentation of the survey communicates an interest in learning about Muay Thai experiences rather that just injury. As Marcus and Lindner (2005) noted, the science of a survey topic can affect the response rate to the survey instrument. As noted earlier concerning the in-person approach, discussing injury outcomes prior to a fight may serve to antagonize the fighter and result in a loss of interest. A survey by definition that discusses the sport more generically that removes the prominence of injury reporting may serve to increase responses. Future research efforts should address this issue to increase our understanding of it.

When considering the information collected from targeted participants regarding the surveillance approaches, there emerge several highlights to improve future surveillance attempts. The electronic distribution methods timed 1 week after the fight occurred produced significantly better response rates. Using the email list warehoused by the sanctioning body yielded the best contact rate. Additional considerations would include removing the mention of injury to describe the survey and calling it a fighter survey, as it is important to collect information on the non-injured participants as well. Another consideration would be to use a pre-notification email to introduce the aims of the survey, to encourage participation, and send reminders to follow up and prompt nonrespondents to participate. Survey methodologists have demonstrated that sending out such correspondence to a panel of participants can increase response rates and data quality when conducting web-based surveys (Lusinchi, 2007).

The current study found an overall injury rate of 55.4% (108/195). There were several notable differences within subgroups of the sample. Injuries were higher in professional fighters 66.7% compared with amateurs (44.4%). Females reported higher rates of injury (66.7%) compared to males (53.9%). Younger fighters reported a higher rate of injury (67.7%) than the older fighters (43.8%). Fighters at a lighter weight reported more injury (64.1%) than those at heavier weights (50.4%). The more experienced fighters reported a higher proportion of injury (69.7%) versus those with less ring experience (46.2%). Fighters who wore more protection during the bout reported a lower incidence of injury (44.7%) compared with the fighters that were less protected (63.6%). Entering the fight with a preexisting injury lead to higher rates of injury (64.7%) compared to fighters that declared they were not injured prior to the bout (50.4%).

The majority of injuries reported were superficial bruises or contusions, to the lower extremities, caused by being struck by the opponent during the fight. The majority of fighters reported that these injuries were minor in severity as they neither impacted the completion of the fight nor the outcome. In other words, the injury did not cause them to stop the fight or determine whether or not they won or lost. Half of the fighters reported seeking medical treatment, with 57.4% being prescribed the RICE (Rest, Ice, Compression, Elevation) Protocol. Most fighters reported taking 1 or more days off from training following the fight (67%). One consideration for the increased frequency of lower limb injuries relates to the Muay Thai scoring paradigm. While all techniques (punches, elbows, knees and kicks) has the potential to score equally in theory, in practice, some techniques score higher than others. Kicks and knees, for example, to the body and head delivered with good technique will score more points, regardless of physical effect. By contrast, punches and elbows have to show a demonstrable physical effect in order to score, and even then, rank lower in the scoring hierarchy. Fighters knowledgeable with the judging rubric, might be more inclined to kick and knee versus throwing punches and elbows. With an increased rate of contact to the lower limbs, then it is plausible to see an elevated rate of injury to this region of the body.

When examining whether or not fight-related injury was related to fight experience, the current study discovered that those fighters that had accumulated more ring experience had 3.2 times ($p<.001$) greater odds of reporting an injury compared to those that had less experience. When looking at the fight experience as a continuous variable, or the total number of fights fought, each additional fight was associated with 1.039 times ($p=.001$) greater odds of a fight-related injury. Professional fighters were 2.59 times (.002) more likely to report a fight-related injury when compared to the amateur fighters in the current study.

When assessing whether or not the level of protective equipment worn by fighters was associated with fight-related injury, fighters wearing the higher degree of protection had .49 times the odds ($p=.018$) of having an injury compared with the fighters wearing less. However, when adjusting for other covariates, level of protection was not found to be statistically significant.

The investigation into whether or not previous injury was related to a fight-related injury in the current study lead to the finding that the fighters who declared having been injured prior to the fight were 1.9 times ($p=.06$) more likely to sustain an injury compared to those who had not been injured previously.

Compared to the previous studies published on Muay Thai (Gartland 2001 & 2005; Shirani 2010), the current study produced many similar results, as well as several noteworthy differences. First and foremost were how the four studies surveyed the participants. Gartland's first research endeavor was performed with one-to-one interviews using a standard questionnaire on injuries incurred during training and practice of Muay Thai. These were conducted at various gyms and competitions in the United Kingdom (UK) and a single Muay Thai gala in Holland. In Gartland's second study, he attended amateur Muay Thai competitions in the UK organized by the International Amateur Muay Thai Federation, a sanctioning body, and while sitting ringside, recorded injuries as referred by the referee or participant to the onsite medics. Shirani's participants were initially seen within a medical setting and referred for oral/maxillofacial consult for specialist treatment, as all injuries were restricted to the head/neck or teeth. The current study surveyed fighters that had recently competed in a sanctioned, or regulated fight.

When compared to Gartland's first retrospective study, the current study echoed that the majority of injuries were to the lower extremities. Gartland reported 64% of the injuries to amateurs and 53% to professionals were to the lower extremities, compared with the current study's similar finding of 55% amateur and 51% professional. Injuries to the head were the 2nd leading body region injured in both Gartland's and the current study. The most common nature of injury in both studies was soft tissue injuries; predominantly contusions. Gartland reported fractures as the 2nd leading nature of injury among professionals, while the current study found slightly more lacerations (20%), followed by fractures (13%). The lacerations were generally (75%) the result of cuts from elbows to the head in the current study. Elbows are a dangerous technique rarely used in training exercises unless wearing heavy padding to reduce the potential danger of being cut. Gartland included training exercises as an exposure, and the absence of this technique in practice could explain the lower incidence of lacerations.

Both Gartland (14-51 years) and the current study (18-47 years) reported similar age ranges with identical 26 year old medians. The distribution of gender in the current study was similar with Gartland's sample comprised of 13% females, compared to 17% in the current study. While Gartland reported injuries among novice, amateur and professionals, he noted that there was confusion from participants about these definitions. It is probable, since training exercises were included in his exposure levels, that not all participants were fighters, therefore had difficulty self-identifying their rank or caliber within the sport.

The current study looked exclusively at fight exposures, resulting in fighters that self-defined themselves categorically as professional or amateur more resolutely. Because training exposures were included in Gartland's study, there were considerably less intense contact levels when compared to this study's single exposure, that is, a fight. Gartland reported a varying range of contact levels: “none”, “touch sparring”, “full contact” and “competition”, with competition and full contact somewhat analogous to a fight. Our contact level only included fights, where all techniques would be delivered with full speed and power, considerably more energy expended than in at least 2 of Gartland’s levels which would be limited to training exercises. This difference may account for his relatively small percentages of time off training (7%), defined as 7 days or more compared to 25.9% found in the current study.

In the second prospective study conducted in 2005, Gartland sampled a younger (mean 17 years), amateur population at tournament competitions. Injuries were reported by the referee, medic or the participant, compared to the current study only documenting self-report. The finding of lower extremity injuries ranking as the most frequent body region injured was not identified in this study, contrary to his finding 4 years earlier. This result might be expected since the fighters were involved in tournaments that mandated that shin pads be worn by all participants, therefore reducing injuries to the lower leg. One unresolved question was whether wearing shinpads required to protect the fighter attacking, the opponent, or both? This was not explicitly mentioned by Gartland as to which participant was thought to be protected by the mandated equipment. It was not clear in Gartland’s results if the leg injuries were the consequence of being stuck by the opponent, or striking the opponent. The author speculated that additional reasons why the head ranked higher within his sample and not the lower leg, is that it might be an acceptable norm to incur minor bumps and bruises and these are not perceived to be injuries by the participant. Wearing shin pads may conceal minor injuries rendering them undetectable by a referee or medic, leading to under-reporting, whereas noticeable contact to the head, as witnessed by the referee, may have lead to increased reporting to the medics for precautionary measures.

Information on the mechanism of injury, protective equipment worn and a brief narrative was collected in the present study. Of the 44 injured amateur fighters, 25 incurred injuries to the lower extremities (7 not wearing shin pads; 18 padding worn). The brief narrative description revealed that the majority of these 16/25 were a consequence of being struck by the opponent, who presumably would also be wearing shin pads, as fighters wear the same level of protection in sanctioned fighters. Damage inflicted to the lower extremity was reported by fighters while wearing protection, against a similarly padded opponent. This increased level of detail was absent from Gartland's results.

Gartland concluded that younger, less experienced and heavier fighters were at increased risk for injury. This is a very different result than reported in the current study, which was that younger, *more* experienced and *lighter* fighters were at increased risk. Gartland did not include professionals, and reported a mean of 3.4 fights within his amateur sample, compared to the 16 fight mean in this study, with nearly 50% professional fighters. A bias was also noted in Gartland's study in the heavier weight classes due to extremely small sample size (n=4) with a considerably high number of injuries reported, therefore, take caution with the generalizability of the statement regarding weight and the association of risk.

A possible explanation for why less experienced fighters were at increased risk in his study compared to the current work might be due to the level of intensity. Younger, experienced professionals are more adept and often driven by fight incentives such as purse or prize money and titles. Considerably more skillful, coupled with a winning drive may lead to more furious efforts when compared to to the relative neophytes in Gartland's sample, still learning and honing techniques, both offensively and defensively.

Gartland also reported injury rates based on competition minutes recorded at the events. He identified an average rate of 9.1 injuries/100 minutes of competition. In the current study, looking at the 44 injured amateurs, and looking at bout time fought, per fight (3 round x 2 minutes), this results in roughly 264 minutes of competition time. This would be an overestimate, as fights stopped during the round were rounded up, as not every bout went the distance, and some less experienced amateur may fight 1.5 minute rounds, although rare. This results in 16.6 injuries/100 minutes competition time, slightly higher than Gartland’s rate, and perhaps how the injuries were reported (referee, medic, some self vs. self-report) lead to more underreporting in his sample.

Shirani’s publication investigated a sample of 120 professional and amateur participants across boxing, tae kwon do, kickboxing and Muay Thai who incurred maxillofacial trauma referred to physicians. Within the subset of Muay Thai fighters, lacerations were the most common outcome (93.3%) and more injuries were reported among the professionals (86%) compared to the amateurs (42%). While this study is not directly comparable to Shirani’s, there were more professionals injured (65%) than amateurs (44%) and more head injuries among the professionals (33% vs. 25%). The professionals with head injuries in the current study did report lacerations (57%) injuries to the jaw (14%), concussions with pain (24%) and several eye injuries (5%). Those cut in all cases sought medical treatment, largely for sutures for the lacerations. This group presented with considerably severe injuries, although it was not specified how, where or when these occurred. There was no information on whether the exposure was in training or a fight, but simply “participation”. Further, the mechanism of injury was not presented, only the nature of the injury itself. The current work collected this information, and found that the majority of the facial lacerations to the professional fighters (84%) were from being elbowed, kneed (8%) or punched (8%) by the opponent.

When comparing key findings from published studies on mixed martials arts (MMA), the current study found higher overall proportion of injury in Muay Thai from the self-report data (108/195; 55.4%) versus MMA. The MMA literature relied on ringside physician exams, perhaps accounting for under-reporting of minor injuries. Both studies uncovered losing fighters more at risk (OR = 2.4, 2.5 respectively). Although losing fighters did declare significantly higher injury severity, this study found no significant difference in injury outcome whether the fighter won or lost the bout. However, because the MMA studies only included professionals, when selecting only the professionals (n=96) in this study, there was slight, but not statistically significant increase in risk (OR = 1.3; p=.56) when losing a fight. Younger fighters (≤26 years) were found to have an elevated risk for injury outcome in this study (OR=.252; p = .004), contrary to Bledsoe's finding, that older fighters were at increased risk (OR = 2.69, 95% CI 1.44-5), but only once controlling for age and weight. In the current study, there were a considerably high number of experienced, professional fighters under the median age (26 years). This group could have begun competing a younger age and accumulated years of training and competing, as Muay Thai has been more widespread as a sport, while MMA has only surged in popularity and participation within the past decade. Participants in MMA with experience may actually be a slightly older group within that sample, which is the opposite of the sample in this study.

Dudek's research (2011) on kickboxing included both heavy training and fighting, noting that the bulk of injuries came from fighting, and often lead to recuperation periods or time off from participation among 53% of the kickboxers. Similarly, the current study found that 66% of fighters reported missing at least one training day after fighting. Most injuries involved were contusions, followed by sprains, however the body region nor the mechanism of injury was presented. The author did report a statistically significant finding that when physical fitness deteriorated following time off from participation, there was an elevated threat of repeat injury. Within this sample, participants reported multiple injuries over the duration of the study period. The current study found that fighters entering a fight with a previous injury due to some level of participation elevated the risk of injury (OR=1.9, p=.06). Dudek's results suggested a multifactorial dependence on injury outcome that could involve too short a recuperation period, improperly treating an injury and insufficient fitness levels.

Zazryn (2003) noted that a majority of kickboxing injuries to professional fighters was to the head (53%) followed by the lower extremities (39.8%), also resulting in 17.5% concussions. The current research endeavor found the lower extremities to be the primary region injured among the 96 professionals (54.7%), followed by the head (33.3%), and with less concussions (7.8%). One reason for this difference could be that in Zazryn's work, all styles of kickboxing were included. There was no differentiation from 4-points of contact (punching & kicking only) and 8-points of contact as in Muay Thai (punching, kicking, elbowing, kneeing). With a more limited arsenal, and only 2 body regions for contact in the western style, this may have contributed to a higher proportion of head injuries than compared to Muay Thai. Zazryn did note that there was a difference in injury outcome whether the fighter won (30.1%) or lost (62.9%). The current study found that compared to non injured fighters, while injured fighters were 1.3 times more likely to have lost, this did not prove to be statistically significant (p=.556).

Within the boxing literature, studies evaluating higher levels of intensity (Zazryn, 2003; Timm, 1993) reported a majority of injuries to the head, mostly superficial lacerations and contusions, followed by concussions. Zazryn only evaluated fights, citing 15.9% of injuries were concussions, while Timm reported 6.1%. The current work found 5.5% self-reported concussions with pain among fighters. This was 1/3 of Zazryn's report, and similar to Timm's with the exception that his study allowed for participation in both fights and sparring. Sparring is normally distinct from fights in competition, since the goal of sparring is an educational exercise for skill development of the participants. Generally, extra precautions are taken to protect the participants, and this may include wearing protective gear, declaring certain techniques and targets off-limits, playing slowly or at a fixed speed, forbidding certain kinds of strikes, thereby changing the nature of the competition. The level of contact is also variable, lighter contact may lead to less injuries but hard contact may better prepare individuals for competition. While a fight is also competed at 100% effort, sparring varies considerably so the participant learns to improvise, to think under pressure, and to keep their emotions under control. Including sparring participants may present in a considerably lower rate of concussion, as the intensity is deliberately adjusted so as to prevent this outcome. Porter (2005) found that the majority of neurological injuries typically occurred during competition in a sample of amateur boxers. He also noted the injury risk rose with the number of previous matches and age. The current research also found that an increase in experience elevated injury risk (OR=3.6, p=.000), but on the contrary, found that younger participants were at more risk (OR=3.4, p=.000). The discordance may lie within the sample comparisons, as this work included both amateur and professionals, and noted a cluster of younger professionals, with considerable experience in the ring.

Dudek's 2011 paper also looked at a small sample of boxers (n=41) that participated in all aspects of boxing training, from running for increasing fitness, to fights. In the self-reports from this sample, there was a very low incidence of concussion, with the majority of injuries superficial contusions, lacerations, and a very small amount of facial fractures requiring medical intervention (19.5%) although it was unclear when these occurred (i.e., fighting, sparring), or whether or not the participant was concussed.

In all of the boxing studies, the majority of injuries were not deemed severe, and often treated on site, if reported. Comparatively, the current study also noted, even within a high level of intensity, such as a fight, the majority of injuries were minor in severity and self-treated.

In Gartland's first publication, he concluded that the rates of injury in Muay Thai were similar to those found in traditional martial arts (TMA), specifically, karate and tae kwon do, which is not surprising, given those sports also place a heavy emphasis on kicking, and the lower extremity is the primary region of injury. Stricevic and Zemper restricted their exposures to tournament level participation, quite similar to Gartland's first retrospective study in which surveyed participants at Muay Thai tournaments as well as within training facilities. However, in his second publication, Gartland concluded that Muay Thai injury rates were higher than those in karate and tae kwon do, when he looked exclusively at the tournament setting. When comparing the current study to previously reviewed publications on injuries within TMA (Beis, Birrer and Halabchi, and Kazemi), analogous findings included similar injury outcomes - lower extremities were the body region most injured, followed by the head/neck. When looking at participation in karate and tae kwon do during competitions, Kazemi noted the leading cause of injury was being kicked by the opponent, followed by kicking them, and injuring one's self. The current work also noted the majority of the injuries were a consequence of being kicked by the opponent, followed by colliding with the opponent or clashing knees/kicks and finally, striking the opponent while kicking, leading to self-injury.

The overall injury rate found in this current work (55%) was higher than those reported in the traditional martial arts, echoing the result from Gartland's second, prospective work in 2005. The majority of the karate and taekwondo reports were documented if the participants sought medical treatment, and in the current study, all levels of self-reported injury were recorded, not only those that sought medical treatment, which accounted for exactly 1/2 of the total injuries.

7.1.1 Limitations

We distributed an electronic survey to Muay Thai fighters who then chose to complete it. This introduces self-selection bias since fighters who have had injuries may be more likely to complete a survey targeting injury outcomes. Alternatively, because we only surveyed active fighters, it is possible that any fighter injured and subsequently quit participating may have been missed. Additionally, we employed a non-probability sample, or convenience sample, therefore introducing sample bias, and therefore the results are not representative. However, as the population of Muay Thai fighters is less tangible, extrapolating back to that target population was not a primary objective, but rather to investigate the relationships between several key variables among those sampled.

We defined an acute injury as painful injuries sustained during an actual fight, and asked respondents to consider fight-specific injuries (in the ring), rather than those sustained during training prior to the fight. If multiple injuries were sustained, the primary injury of interest was the injury the fighter felt was the most severe. This study did not capture all of the injuries during the fight, but focused on a single injury that was self-reported to be the most severe. Additionally, as the case definition concentrated on the pain aspect of the injury, it does not factor in that the mechanism of injury could have started prior to the fight without the emergence of pain. As pain threshold is an entirely subjective phenomenon, some individuals may tolerate higher levels of pain compared to others, therefore resulting in differences in reporting injury according to the current study's case definition. For example, the identical injury occurring for 2 different fighters may result in only one reporting the injury based on the definition focusing on reported pain. Additionally, fighters may have not experienced pain with concussion, therefore may not have disclosed an injury which conceivably could lead to underreporting of concussions within this study.

The retrospective nature of the study design introduces the possibility of recall bias. By design, the current study restricted the recall period to a maximum of 6-months, since Gabbe's publication (Gabbe, 2003) found that injury rates over a 1-year time period had perfect recall whether an injury had occurred, with decreasing percentages of participants recalling the exact number, body region or diagnosis. Therefore, it stands to reason that the current study's injury rate is likely to be accurate, perhaps with decreasing accuracy in the reported total number of injuries, location and diagnosis obtained from self-reporting. There were 2 different recall periods, as within the targeted sample, fighters were approached within a week of fighting, compared to the convenience sample that allowed for injury recall up to 6 months. Training injuries were not included in this survey, another limitation, though previous fights with an injury sustained were documented by asking fighters "how many fights have you had in the past 6 months where you sustained at least 1 injury?"

The current study had a small sample size for female fighters, and as logistic regression overestimates odds ratios in studies with small to moderate samples size, this may have induced a systematic bias, and therefore caution is urged when interpreting the resulting association that females reported increased levels of injury when compared to males.

Despite these limitations, the current study also has several advantages. Our injury criteria were concrete, and encompassed a wide range of injuries seen within the combat sports, particularly within Muay Thai, having been assembled by trainers, fighters and officials within the sport. Although not validated, the survey piloted a means of electronic delivery for web-based surveying, which could easily be replicated on a grander scale among more participants. This was structured as a pilot study which could provide areas of focus for further studies. A larger, prospective study with a validated survey and examination of injury rates and patterns with elements related to experience, protection, preexisting injury, length of time in the sport (stratifying for amateur and professional fight exposures) and training activities may then be explored in more detail to help design effective prevention strategies to reduce injury rates and aid Muay Thai grow into a safe and effective sport and recreational activity.

7.1.2 Conclusions

Recruitment and surveillance efforts for Muay Thai fight-related injury should consider electronic distribution methods timed shortly after the fight, using the email addresses provided by sanctioning bodies to yield the best contact and response rates. Distributing invitations for a “Muay Thai participation survey” would perhaps peak interest among all participants, thereby including the injured and non-injured and subsequently collecting more complete information regarding fight-related outcomes. Using pre-notifications explaining the aims of the survey and to encourage participation, as well as sending gentle reminders to prompt nonrespondents may increase response rates and data quality.

Within this study, more than half (55.4%) of the fighters sustained an injury within their most recent contest. Soft-tissue injuries were most commonly reported (66.7%), followed by fractures (13.1%) and concussions (5.4%). Injuries occurred to the lower extremities most often (53.7%) followed by those to the head (30.6%) with the remainder to the torso (10.8%) and upper extremities (4.9%). Most damage was inflicted as the result of being struck by the opponent (68%), followed by collisions with the opponent (12.3%) and as a consequence of striking the opponent and injuring one's self (8.1%). The impact of the injuries in terms of severity was not reported to be very high, as the most common injuries were deemed as those that did not interfere with the completion of the fight, nor did they affect the fight outcome (66.7%). Severe injuries were uncommon in this study population, as only 11.3% reported the injury did interfere with completion of the fight, and affected subsequent training/fighting. Concussion within this sample of Muay Thai fighters was particularly low, with only 6 (5.4%) of participants declaring this was the primary nature of the injury, and 5/6 were among the professional fighters. While 2/3 did report taking time off from training, and 11% canceled a scheduled fight, 50% reported the injuries required no treatment, or were self-treated. Those seeking medical treatment (50%) were prescribed the RICE protocol in 58% of the cases. Overall, when looking multivariate, the current study found several unique and significant relationships: the fighters at greater injury risk were younger, female, had more ring experience, were professional caliber fighters, and entered the fighter having declared a pre-existing injury.

7.1.3 Future Directions

Muay Thai continues to emerge as a popular combat sport. As participation continues to expand, injuries associated with involvement will likely grow commensurately. The lower extremities were the most commonly injured body regions injured during fights, and were predominantly superficial and mild in severity. Although concussion represented a small proportion of reported injuries in the current study, there should remain a focus on head injury as many sports both professionally and recreationally are now addressing this issue. While we did not see high incidence of head injury cross-sectionally in single fights, there may be cumulative effects to track longitudinally. In a recent study that sampled all registered retired boxers in Thailand (Sports Authority of Thailand; the Boxer's Club of Thailand & Thai Boxing Foundation) eligible participants were recruited by mail and telephone follow-up to complete and return a paper questionnaire (73.3% response rate). Investigators reported that an association with the number of professional bouts (>100 fights) and Parkinson's Disease. Among these boxers, they support the notion that repeated head trauma can be cumulative resulting in slowly evolving processes of neurodegeneration (Lolekha, 2010).

In terms of surveillance, future directions should consider looking at professional and amateur fighters separately, as one is essentially an occupational exposure and the other recreational. The amount of time in a fight varies between the two groups, rules are often adjusted for amateurs to reduce injury, and generally more protection is mandated. Because this group represent both hobbyists and less adept combatants, the fight exposure varies slightly when compared to professionals. Professional fighters are compensated for their performance and the inherent risk of injury that may occur in the fight. There are often additional financial incentives, such as a win or knockout bonus and fight of the night honors.

In addition to fight surveillance, training exposures should be explored through future surveillance. This would not only include the professional and amateur fighters, but also those simply training for fitness and recreation. Training injuries among the fighters would be important to investigate prospectively as the training cycle leading up to a completed figth may impact fight injury outcomes.

In summary, we identified a preliminary fight-related injury rate, coupled with the characteristics of fighters associated with fight-related injuries; the most common location of injury; the nature, mechanism and severity of injury; fight level factors such as experience level, protection level and existence of previous injury associated with injury outcome. While unique associations, they require more rigorous research exploring causal factors. However, the current information can be used by fighters, trainers and officials who participate directly in the sport to prevent and treat injury. It cannot be overemphasized how important it is for all individuals involved in the decision-making process to be fully informed as to what factors may impact a fighter's injury process.

APPENDIX A: IRB STUDY APPROVAL

OSIRIS Request for Exempt Determination: **Tests, Surveys, Interviews, or Observations of Public Behavior**
Title of Study: MuayThai Injury Surveillance during Sanctioned Fight Events
Principal Investigator: Last name: **Strotmeyer** First name: **Stephen**
<u>Note</u>: This exemption is limited to individuals 18 years of age or older. Subjects under 18 can be evaluated with educational tests <u>only</u> (<u>no</u> surveys or interviews). They can also be observed in public places, but only so long as researchers do not participate in the activities being observed.
A. Check type(s) of measures to be used: Passive Observation of Public Behavior; Educational Tests (cognitive, diagnostic, aptitude); x Survey; Interview; Other (Describe) ***** Have copies of all measures or questions been attached? No xYes . If no, why not?
B. Is a script attached (or inserted in question 5a) **that describes the study to the subject and includes basic elements of consent (e.g., risks and benefits, confidentiality of data, right to withdraw; for model, see** http://www.irb.pitt.edu/Exempt/script-1.pdf**)? No XYes NA .** If no, why not?
C. ***If applicable*****, have recruitment materials been attached and uploaded** (or inserted in question 4b)**? No Yes NA .** If no, why not?
D. Will subjects under 18 years of age be studied? xNo Yes ; If yes, to what extent will researchers interact with subjects?
E. Will information be recorded anonymously (i.e., no subject identifiers recorded)? No xYes ; If identifiers are recorded, provide justification:
F. Will "sensitive information" be recorded that could damage subjects' reputation, employability or financial standing, or place them at risk for criminal or civil liability? **x**No Yes . If yes, explain:
G. Will any information from this project be submitted to the FDA? x No Yes

Study Aims

IRB Protocol

What is this research intended to accomplish? 1. To examine the feasibility of establishing a surveillance system for muayThai fight-related injuries.

Quantitatively assess by calculating response rate, cooperation rate, contact rate and refusal rates.

Qualitatively assess the timing window for maximizing contact and participation in the surveillance system.

Descriptive Aim: To describe the frequency and severity of muayThai fight-related injuries among a sample of professional and amateur fighters.

Determinant Aims: To study the determinants of muayThai fight-related injury.

To determine if fight-related injury is related to years of fight experience.

To determine if fight-related injury is related to degree of protective equipment worn.
To determine if fight-related injury is related to pre-existing injury.
To explore underlying demographic factors (e.g., age) associated with injury outcome.

Background and Significance

What observations or prior scientific findings serve as the basis for this study? Currently there are no surveillance systems setup to record injuries to muayThai fighters. MuayThai is a global sport with recent recognition by the International Olympic Committee and is being pushed for inclusion in the games, with participation growing as evidenced by more than 100 countries participating in the world championships annually.

Why is it important to conduct this research? A previous study reported injuries only to amateur in tournament format, and we aim to provide more in depth epidemiologic descriptions as the the injuries among fighters and to test the ability to conduct surveillance as part of a dissertation project.

Subjects

Who will be studied? MuayThai fighters 18+ years participating in sanctioned fights as amateurs or professionals.

If children are included… **x**Not Applicable ☒

Provide a rationale for the specific age ranges of children to be included.

Describe the expertise of the investigative team for dealing with children of that age range.

Describe the adequacy of the research facilities to accommodate children of that age range.

Will sufficient numbers of children be studied to answer the scientific questions? Please elaborate.

Will the investigators interact directly with the child subject? No ; Yes

Is the research limited to educational tests or observations of behavior?

No ; Yes

Recruitment

How will potential subjects be identified and how and where will they be approached for participation? Subjects will be identified from permitting sanctioning organizations that promote fight events for muayThai. (See approval/support letter). The consent form will include the URL and will adequately explain the study at the time of recruitment. Subjects will be recruited by providing sanctioning bodies with that recruitment letter for distribution (email, letter, online posting) for eligible respondents to choose whether or not they wish to participate. Individuals will not be cold called from lists provided by the sanctioning body.

Describe recruitment materials (*ads, letters, recruitment script, etc.*) **to be used and if applicable, upload 1 copy**. Recruitment/Consent Letter;

Methods

Attach a script that provides participants with information about this research project as well as about their rights as a research subject. Attached

How will subjects be evaluated? No evaluation.

List the measures to be used, and upload 1 copy of each (unless measure does not require submission – see listing of Standard Instruments in Appendix G of IRB Manual). HTML survey attached.

How will information be obtained (e.g., face to face, phone, mail, Internet)? Internet Survey

Where will study be conducted, and who will collect data? Data collection will be conducted by the PI at the University for Social and Urban Research.

How often will subjects be contacted, and why? Eligible subjects will be contacted either in person during an event or after an event (internet). A followup reminder will be emailed to complete the survey if they have not already submitted responses 2 weeks post event.

How will confidentiality of data be maintained? No identifiers will be collected and data will reside on secure servers at UCSUR.

If subjects will be paid or otherwise compensated or 'incentivized', indicate how much they will receive, and how they will be compensated (e.g., check, gift card / voucher, etc.).

Analysis

How will results be analyzed to determine that study aims have been met? General Hypotheses include the following, to be analyzed using appropriate statistical techniques, such as logistic regression modelling. :

•If fight-related injury is related to experience, then fighters with less experience will have higher injury frequency and severity.

•If fight-related injury is related to protective equipment, then fighters with less protection will have higher injury frequency and severity.

•If fight-related injury is related to pre-existing injury, then fighters with training injuries leading up to a fight will have higher injury frequency and severity.

Summarize the qualifications and experience of the Principal Investigator that are relevant to the conduct this research study: Stephen Strotmeyer is a doctoral student in the department of Epidemiology and a senior survey researcher at the University Center for Social and Urban Research. He is combining his expertise in survey methods, training in Epidemiology and personal experience in the sport of MuayThai to study the feasibility of surveying muayThai fight injuries, to collect & analyze data and present in dissertation format as required for a PhD

Additional Information, Clarification, or Comments for the IRB Reviewer: .

*******CERTIFICATION OF INVESTIGATOR RESPONSIBILITIES**

By submitting this form to the IRB via OSIRIS, I agree/certify that:

I am cognizant of, and will comply with, current federal regulations and IRB requirements governing human subject research including adverse event reporting requirements.

I have reviewed this protocol submission in its entirety and that I am fully aware of, and in agreement with, all submitted statements.

I will conduct this research study in strict accordance with all submitted statements except where a change may be necessary to eliminate an apparent immediate hazard to a given research subject. If such a change is made – only to ensure the immediate safety of a research subject – I will subsequently report that protocol deviation to the IRB as soon as possible.

I will request and obtain IRB approval of any proposed modification to the research protocol that may affect its exempt status prior to implementing such modification.

I will ensure that all co-investigators, and other personnel assisting in the conduct of this research study have been provided a copy of the entire current version of the research protocol.

I will ensure that all members of the research team have satisfactorily completed the Research Integrity (module 1) and Human Subjects Research (module 2a or 2b) web- based training programs.

I will not enroll any individual into this research study until the exempt status of this application has been determined by the IRB and I have been informed in writing.

I will respond promptly to all requests for information or materials solicited by the IRB.

I will maintain adequate, current, and accurate records of research data.

I will not knowingly include prisoners.

End of Application (Form: EXESUR 041707)

APPENDIX B: LETTER OF SUPPORT

World Kickboxing Association

August 4, 2010

Re: Muay Thai Fighter Research Project

Mr. Strotmeyer:

As a prominent regulatory body of the sport of Muay Thai, we are happy to support you in your research into the magnitude, scope, and risk factors for injury within the sport so that the Muay Thai community as a whole is better informed and better able to keep its participants safe. The mission of WKA is to hold safe, fair, and competitive sporting events. Anything that your research can do to enhance this mission, we will be in full support of.

Sincerely,

Brian Crenshaw
WKA US Representative
World Vice President - Ringsports
Muay Thai, Kickboxing, Full Contact,
MMA, Grappling
10454 Ridgefield Pkwy.
Richmond, VA 23233 USA
804-937-7072
info@wkausa.com
www.WKAUSA.com

APPENDIX C: SURVEY INVITATION

Muay Thai Fighter Survey

Dear Nakmuay,

Congratulations on your outstanding ring accomplishments in muayThai! As a fighter, you have been personally selected to participate in *The MuayThai Injury Surveillance during Fight Events* study, an innovative research study investigating injuries incurred during muayThai fights.

If you are 18 years of age or older, please share your experiences in our approximately 10-15 minute online survey by visiting www.survey.pitt.edu/muaythai when you have internet access.

Alternatively, you can have a direct link emailed to you by the Principal Investigator by emailing Stephen Strotmeyer at sjsst43@pitt.edu. Rest assured that all of your answers will be used only for scholarly purposes and will be kept completely confidential.

Your participation is absolutely critical to the success of this project. Only through your responses can we better understand the injuries resulting from participation in muayThai, the “King of the Ring”. Gaining better insight into the magnitude, scope and risk factors for fight injury will allow the development of future prevention and intervention activities.

Thank you again for your so very generous participation.

Stephen Strotmeyer, MPH
University of Pittsburgh
Center for Social & Urban Research

Thomas J. Songer, Ph.D.
Assistant Professor
Department of
Epidemiology

APPENDIX D: SURVEY INSTRUMENT

MuayThai Injury Surveillance during Sanctioned Fight Events

You are being invited to participate in a research study about muayThai injuries resulting from fights, with the purpose of studying the frequency, nature, and determinants of these injuries during competition. This study is being conducted by Stephen Strotmeyer, MPH and Thomas Songer, PhD. from the Department of Epidemiology at the University of Pittsburgh, as part of a doctoral dissertation.

You were selected as an eligible participant in this study because of recent participation in a sanctioned muayThai fight. There are no known risks if you decide to participate in this research study. There are no costs to you for participating in the study. The information you provide will be used to describe the frequency and severity of muayThai fight-related injuries among a sample of professional and amateur fighters.

The questionnaire will take about 10 minutes to complete. The information collected may not benefit you directly, but the information learned in this study should provide more general benefits.

This survey is anonymous. Do not write your name on the survey. As this is a web-based survey, we will not be tokenizing respondents or collecting IP addresses. The servers are secure, and we will provide anonymity, but absolute anonymity cannot be guaranteed over the internet. No one will be able to identify you or your answers, and no one will know whether or not you participated in the study. Individuals from the University of Pittsburgh and the Institutional Review Board may inspect these records. Should the data be published, no individual information will be disclosed.

Your participation in this study is voluntary. By completing and submitting your responses to the web survey, you are voluntarily agreeing to participate. You are free to decline to answer any particular question you do not wish to answer for any reason.

If you have any questions about the study, please contact Stephen Strotmeyer, 121 University Place, University Center for Social & Urban Research, 412-624-3857 or email sjsst43@pitt.edu or Thomas Songer, PhD tjs+@pitt.edu The University of Pittsburgh Institutional Review Board has reviewed my request to conduct this project. If you have any concerns about your rights in this study, please contact please contact the Human Subjects Protection Advocate at 1-888-212-2668.

By clicking "Yes" below you acknowledge that you have read and understand that:By clicking "Yes" below you acknowledge that you have read and understand that:

•Your participation in this survey is voluntary. You may withdraw your consent and discontinue participation in the project at any time. Your refusal to participate will not result in any penalty.

DO YOU WISH TO PARTICIPATE IN THIS STUDY?

☐ YES, I WANT TO PARTICIPATE

☐ NO, I DO NOT WANT TO PARTICIPATE

IF YES…

ARE YOU AN ACTIVE MUAYTHAI FIGHTER (i.e., YOU PARTICIPATE IN BOUTS RANGING FROM INTERCLUBS/SMOKERS TO FULL RULES PROFESSIONAL)?

☐ YES

☐ NO

IF NO

CURRENTLY, WE ARE ONLY SURVEYING ACTIVE MUAYTHAI FIGHTERS.IN THE FUTURE, WE PLAN TO SURVEY NON-FIGHTERS AS WELL. THANK YOU FOR YOUR TIME.

1.3) WAS YOUR MOST RECENT FIGHT AS A/N:

☐ PROFESSIONAL FIGHTER (Paid a fight purse -OR- A, B, C Class fight without padding.)

☐ AMATEUR FIGHTER (Unpaid -OR- protective padding worn during the fight.)

1.2)HOW MANY TOTAL MUAYTHAI FIGHTS HAVE YOU HAD?

(PLEASE SPECIFY A NUMBER IN EACH CATEGORY BELOW, INCLUDING '0' IF YOU HAD NO FIGHT WITHIN THAT CLASS.

A class 5x3 _____
B Class 5x2 _____
C Class 3x2 _____
C Class 5x1.5 _____
NOVICE/INTERCLUB/SMOKER _____
OTHER _____

2.1) HAVE YOU FOUGHT WITHIN PAST 6 MONTHS?

☐ YES
☐ NO

SCREENER HAVE YOU HAD AN INJURY IN A FIGHT WITHIN THE PAST 6 WEEKS?

☐ YES
☐ NO

2.2)HOW MANY TOTAL MUAYTHAI FIGHTS HAVE YOU HAD IN THE PAST 6 MONTHS?

(PLEASE SPECIFY A NUMBER IN EACH CATEGORY BELOW, INCLUDING '0' IF YOU HAD NONE UNDER ANY CLASS.

A class 5x3 _____
B Class 5x2 _____
C Class 3x2 _____
C Class 5x1.5 _____
NOVICE/INTERCLUB/SMOKER _____
OTHER _____

INJURY DEFINITION

We are interested in painful injuries sustained during an actual fight. Please consider fight-specific injuries (in the ring), rather than those sustained during training prior to the fight.

2.8) HOW MANY FIGHTS HAVE YOU HAD IN THE PAST 6 MONTHS WHERE YOU SUSTAINED AT LEAST 1 INJURY ?

☐ 1
☐ 2
☐ 3
☐ 4
☐ 5
☐ 6
☐ More than 6

2.9) WAS THIS INJURY ...

(note: IF YOU SUSTAINED MULTIPLE INJURIES DURING THE FIGHT, WE ASK YOU THINK OF THE MOST SEVERE, SINGLE INJURY FOR THE FOLLOWING SERIES OF QUESTIONS. WE WILL REFER TO THIS AS THE PRIMARY INJURY)

☐ NEW INJURY (i.e., sustained during the fight)
☐ AGGRAVATED INJURY (i.e., an injury sustained during fight training was aggravated during the fight)
☐ RECURRENT INJURY (i.e., an injury sustained in the past that recurs periodically in training/fights)
☐ OTHER

2.10) OTHER INJURY (PLEASE DESCRIBE)

____
____
____
____
____

2.11) WHEN DID YOU SUSTAIN YOUR MOST RECENT FIGHT-RELATED INJURY?
DATE (DD/MM/YYYY) ____

2.12) INJURY TIME (HH:MM)

____

2.12)a WHERE WAS THIS EVENT AND WHO SANCTIONED IT?

____
____
____

2.13) WHAT WAS THE PRIMARY BODY REGION INJURED?
(SELECT ONE)

- ☐ HEAD/NECK
- ☐ TRUNK/TORSO
- ☐ EXTREMITIES (ARMS, LEGS)
- ☐ OTHER

2.14) BODY PART, SPECIFY

____

2.15) WHAT WAS THE NATURE OF YOUR PRIMARY INJURY?

(SELECT ONE)

- ☐ ABRASION
- ☐ BRUISE/CONTUSION
- ☐ CONCUSSION/LOSS OF CONSCIOUSNESS
- ☐ DISLOCATION/SUBLUXATION
- ☐ RESPIRATORY PROBLEMS/FATIGUE
- ☐ FRACTURE
- ☐ INFLAMMATION/SWELLING
- ☐ OPEN WOUND/LACERATION/CUT
- ☐ OVERUSE INJURY TO MUSCLE/TENDON
- ☐ SPRAIN (LIGAMENT/JOINT)
- ☐ STRAIN (MUSCLE/TENDON)
- ☐ OTHER

2.16) NATURE OF PRIMARY INJURY, SPECIFY

____

2.17) PRIMARY CAUSE OR MECHANISM OF INJURY

(SELECT ONE)

- ☐ STRUCK BY
- ☐ FALL
- ☐ COLLISION
- ☐ OVEREXERTION
- ☐ LIFTING/PULLING
- ☐ OTHER

2.18) CAUSE OF PRIMARY INJURY, SPECIFY

____

2.19) INJURY INCIDENT EXPLANATION

PLEASE DESCRIBE HOW THE INJURY HAPPENED BELOW:

____
____
____

2.20) WHAT INITIAL TREATMENT WAS GIVEN?

(SELECT ALL THAT APPLY)

- ☐ NONE REQUIRED
- ☐ SELF-TREATED
- ☐ MEDICAL TREATMENT REQUIRED
- ☐ RICE - REST, ICE, COMPRESSION, ELEVATION
- ☐ SLING/SPLINT
- ☐ CARDIOPULMONARY RESCUSITATION (CPR)
- ☐ TAPING ONLY
- ☐ DRESSING
- ☐ SUTURES/STITCHES
- ☐ CRUTCHES
- ☐ OTHER

2.21) OTHER INITIAL TREATMENT, SPECIFY

____

2.22) WHO TREATED YOUR INJURY?

(SELECT ALL THAT APPLY)

- ☐ NONE
- ☐ NONE (SELF-TREATED)
- ☐ TRAINER/COACH TREATED
- ☐ EMS - EMERGENCY MEDICAL TECHNICIAN OR PARAMEDIC
- ☐ EMERGENCY DEPARTMENT
- ☐ PHYSIOTHERAPIST
- ☐ HOSPITAL (OUTPATIENT)
- ☐ HOSPITAL (INPATIENT)
- ☐ OTHER

2.23) OTHER, TREATED BY

____
____
____

SEVERITYa PLEASE RATE YOUR PRIMARY INJURY SEVERITY LEVEL

(SELECT ONE)

- ☐ LEVEL 0 - INJURY DID NOT INTERFERE WITH COMPLETION OF FIGHT (i.e., INJURY HAD NO BEARING ON FIGHT OUTCOME)
- ☐ LEVEL 1 - INJURY DID NOT INTERFERE WITH COMPLETION OF FIGHT, BUT DID AFFECT PERFORMANCE DURING FIGHT (i.e., YOU WERE LIMITED OR RESTRICTED IN YOUR PERFORMANCE)
- ☐ LEVEL 2 - INJURY DID INTERFERE WITH COMPLETION OF FIGHT, BUT DID NOT AFFECT SUBSEQUENT TRAINING OR FIGHTING (i.e., YOU COULD TRAIN WITHOUT DELAY)
- ☐ LEVEL 3 - INJURY DID INTERFERE WITH COMPLETION OF FIGHT, AND DID AFFECT SUBSEQUENT TRAINING OR FIGHTING (i.e., YOU WERE DELAYED RETURNING TO TRAINING OR WERE HAMPERED IN TRAINING BY YOUR INJURY)

2.24) HOW MUCH TRAINING TIME DID YOU MISS DUE TO THIS INJURY?

- ☐ NONE
- ☐ 1 DAY
- ☐ 2 DAYS
- ☐ 3-7 DAYS
- ☐ 1 WEEK
- ☐ 2 WEEKS
- ☐ MORE THAN 2 WEEKS

2.25) DID YOUR INJURY CAUSE YOU TO CANCEL OR POSTPONE A SCHEDULED FIGHT?

- ☐ YES
- ☐ NO
- ☐ NO - DID NOT HAVE ONE PLANNED

2.26) HOW LONG WAS IT AFTER THE INJURY UNTIL YOU WERE PHYSICALLY ABLE TO FIGHT AGAIN?

- ☐ NONE
- ☐ < 1 WEEK
- ☐ < 2 WEEKS
- ☐ < 3 WEEKS
- ☐ < 4 WEEKS
- ☐ < 5 WEEKS
- ☐ < 6 WEEKS
- ☐ MORE THAN 6 WEEKS

2.27) WHEN DID YOU FIGHT AGAIN?

- ☐ NONE
- ☐ < 1 WEEK
- ☐ < 2 WEEKS
- ☐ < 3 WEEKS
- ☐ < 4 WEEKS
- ☐ < 5 WEEKS
- ☐ < 6 WEEKS
- ☐ MORE THAN 6 WEEKS

2.28) HOW MUCH WORK TIME DID YOU MISS DUE TO THIS INJURY?

- ☐ NONE
- ☐ 1 DAY
- ☐ 2 DAYS
- ☐ 3-7 DAYS
- ☐ 7 + DAYS

(ALL)

2.29) WAS THIS FIGHT CLASSIFIED AS:

- ☐ A class 5x3 FULL THAI RULES
- ☐ A Class 5X3 MODIFIED RULES
- ☐ B Class 5x2
- ☐ C Class 3x2
- ☐ C Class 5x1.5
- ☐ NOVICE/INTERCLUB/SMOKER
- ☐ OTHER

*Full Thai Rules permits use of elbows, in addition to all legal strikes generally seen in Thailand's Stadia.

Modified rules generally prohibit elbows and other techniques such as knees to head.

2.30) FIGHT CLASSIFICATION, SPECIFY

____

2.31) WHAT PROTECTIVE EQUIPMENT WAS WORN?

SELECT ALL THAT APPLY.

- ☐ NONE (GLOVES ONLY)
- ☐ HEADGEAR
- ☐ CHEST PROTECTOR
- ☐ ELBOW PADS
- ☐ SHIN/INSTEP PADS
- ☐ MOUTHGUARD
- ☐ GROIN GUARD
- ☐ OTHER

2.32) OTHER PROTECTIVE EQUIPMENT, SPECIFY

____

2.32)G WHAT WEIGHT GLOVES WERE WORN?

- ☐ 6 oz.
- ☐ 8 oz.
- ☐ 10 oz.
- ☐ 12 oz.
- ☐ 14 oz.
- ☐ 16 oz.
- ☐ 18 oz. or heavier

2.33) WHAT WAS THE FIGHT WEIGHT (kg)?

☐ Mini Flyweight - 105 lbs (47.727 kg.) ☐ Junior Flyweight - 108 lbs (48.988 kg.)
☐ Flyweight - 112 lbs (50.802 kg.) ☐ junior Bantamweight - 115 lbs (52.163 kg.)
☐ Bantamweight - 118 lbs (53.524 kg.) ☐ Junior Featherwweight - 122 lbs (55.338 kg.)
☐ Featherweight - 126 lbs (57.153 kg.) ☐ Junior Lightweight - 130 lbs (58.967 kg.)
☐ Lightweight - 135 lbs (61.235 kg.) ☐ Junior Welterweight - 140 lbs (63.503 kg.)
☐ Welterweight - 147 lbs (66.638 kg.) ☐ Junior Middleweight - 154 lbs (69.853 kg.)
☐ Middleweight - 160 lbs (71.575 kg.) ☐ Super Middleweight - 168 lbs (76.363 kg.)
☐ Light Heavyweight - 175 lbs (79.379 kg.) ☐ Cruiserweight - 190 lbs (86.183 kg.)
☐ Heavyweight - 190 lbs+ (86.183 kg.+) ☐ Super Heavyweight - 209 lbs+ (95 kg.+)

2.34) WHAT WAS YOUR WEIGHT?
_____

2.35) WHAT WAS THE FIGHT OUTCOME?
☐ WON
☐ LOST
☐ DRAW
☐ OTHER

2.36) HOW DID THE FIGHT END?
☐ KO - A Knock-Out is awarded when the opponent is knocked down and unable to continue within the 10 second count.
☐ TKO - A Technical Knock-Out (T.K.O.) is awarded: When a boxer is seriously hurt or weakened.
☐ TKO - A Technical Knock-Out (T.K.O.) is awarded: When a boxer cannot continue the match after the break.
☐ TKO - A Technical Knock-Out (T.K.O.) is awarded: On the doctor's recommendation, when the referee is unsure whether a boxer can continue the match due to injury or being seriously weakened.
☐ TKO - A Technical Knock-Out (T.K.O.) is awarded: Both boxers are seriously injured and cannot continue the match; If less than three rounds: a draw is declared; If three rounds have been reached, individual score decides.
☐ TKO - A Technical Knock-Out (T.K.O.) is awarded: Receiving a count twice in the same round and unable to continue the match.
☐ Winning due to the opponent's retirement because of injury.
☐ Winning due to the opponent's violation of the rules.
☐ Winning on points.
☐ Losing on points.
☐ "No decision" as a result of both parties colluding together to cheat or not fighting properly.
☐ "No contest" as a result of the ring being damaged and the match not being able to continue, or if an external event occurs during the fight, causing it to be stopped.

☐ Draw.

2.37) PLEASE BRIEFLY EXPLAIN HOW THE FIGHT ENDED. (FOR EXAMPLE, YOU KNOCKED YOUR OPPONENT OUT IN THE 3RD ROUND WITH PUNCHES)

____

2.38) IN WHAT ROUND WAS THE FIGHT STOPPED?

- ☐ 1st ROUND
- ☐ 2nd ROUND
- ☐ 3rd ROUND
- ☐ 4th ROUND
- ☐ 5th ROUND
- ☐ NO STOPPAGE

For the next question, please think of the fights you have had within the past six months...

3.1) HOW MANY INJURY-FREE FIGHTS HAVE YOU HAD IN THE PAST 6 MONTHS?

- ☐ 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5
- ☐ 6
- ☐ More than 6
- ☐ NONE

DEMOGRAPHICS

AGE WHAT IS YOUR AGE?

______

GENDER WHAT IS YOUR GENDER?

- ☐ MALE
- ☐ FEMALE

RACE WHAT IS YOUR RACE/ETHNICITY?

____

COMMENT PLEASE FEEL FREE TO COMMENT OR TO PROVIDE FEEDBACK:

____

PLEASE CLICK THE RED SUBMIT BUTTON. THANK YOU FOR YOUR TIME.

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