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The Epidemiology Of Taekwondo Injuries In Youth And Adult Competitors

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THE EPIDEMIOLOGY OF TAEKWONDO INJURIES IN YOUTH AND ADULT COMPETITORS

by

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This thesis, submitted by Matthew Carlson in partial fulfillment of the requirements for the Degree of Master of Science from the University of North Dakota, has been read by the Faculty Advisory Committee under whom the work has been done, and is hereby approved.

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Matthew F. Carlson
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ABSTRACT

Objective: To study the nature and incidence rate of injuries affecting young and adult taekwondo competitors during training and competition and to examine the relationship between injury rates and specific injury risk factors.

Background: Taekwondo is becoming an increasingly popular sport among youth and adult populations. With this increase in popularity, the epidemiology of injury in taekwondo is becoming an increasingly important area of investigation. There has been little research investigating the incidence and distribution of injuries affecting taekwondo athletes, and the research that does exist lacks consistency in research methods. Analytical studies are limited to those which have examined risk factors. The results of these studies are mixed with little consistency in findings across studies.

Method: This study followed both a retrospective and prospective cohort design. Institutional Review Board (IRB) approval was obtained from the University of North Dakota (UND). Taekwondo participants at a local taekwondo academy were invited to participate in this study. Baseline data were collected through a demographic and previous injury history form. Injury surveillance on participants was administered throughout the spring taekwondo season from March 5th, 2013 until May 24th, 2013. Participants were queried on all injuries that they sustained during this period of time. All injuries that were reported to the principal investigator were documented. An injury was defined as "any injury to a body part (as a result of taekwondo) that interferes with

training or competition and is recorded on the first day of onset and every day thereafter until it does not interfere with training or competition." Additionally, exposure to all training and competition was recorded by the researcher in terms of hours and athletic-exposures (AEs).

Once the season was over, study data were entered into a computer system and descriptive analyses were run to determine the incidence and distribution of injury. Due to multiple injuries in some participants, Poisson regression models were fitted using generalized estimating equations to estimate incidence rate ratios (IRR) and to test risk factors. Unadjusted rates were estimated from Poisson regression with each of the following risk factors: age, sex, height, weight, years of experience, rank (high vs. low), previous injury history, specific injury history, and having an unrelated injury during the season. For adjusted rate ratios a multiple-Poisson regression was used with the following risk factors: sex, weight, previous injury history, and having an unrelated injury during the season.

Results: Nine of the 22 participants [14 male (5 youth), 8 female (2 youth)] sustained a total of 16 injuries during the study period. One AE was equal to one hour of exposure. The overall injury rate was 34.86 injuries per 1,000 AEs and 1,000 hours. The overall injury rate for adult males was 68.49 injuries per 1,000 AEs and 1,000 hours, and for adult females was 35.50 injuries per 1,000 AEs and 1,000 hours. There were no youth injuries sustained during this study period. The majority of injuries sustained by males involved the hand/fingers (40%). The majority of injuries sustained by females involved the shoulder (33.33%). The most common injury type in males was laceration and contusion (30%), followed by dislocation (20%). The most common injury type in

females was joint dysfunction in the shoulder (33.33%). All injuries were sudden onset in nature, and 81.25% of the injuries were a new injury. The most common injury situations were blocking a kick (33.33%) and board/brick breaking (33.33%), followed by drills and self-defense holds (16.67%). The most common mechanism of injury was receiving a blow (33.33%) and impact with a surface (33.33%), followed by self-defense holds (16.67%). All injuries were minor in severity.

In the unadjusted Poisson regression analysis of injuries per 1,000 AEs, the following risk factors resulted in a significant effect: age, height, weight, previous injury history, specific injury history, and having an unrelated injury during the season. However, in the multiple Poisson regression, only weight and having an unrelated injury remained significant.

Conclusion: Injury rates reported in this study are generally higher than those reported in previous research. There were no youth injured in this study. Injury rates are reported in athletic-exposures and exposure hours in order to make this study comparable to previous research. Multivariate analyses indicated that weight and having an unrelated injury during the season may be risk factors for injury in taekwondo.

Further research needs to be done on possible risk factors (e.g. height, weight, experience) and preventive measures to further reduce the likelihood for injury during training and competition in taekwondo. Further research should include larger sample sizes, more child subjects, and longer periods of injury surveillance.

CHAPTER I

INTRODUCTION

Taekwondo began as a defense martial art called approximately 5,000 years ago, called “Subak,” “Taekkyo,” or “Sunbae” (World Taekwono Federation, 2012). Traditional Taekwondo (TKD) is a modern sport that originated in Korea in the early to middle 1900’s, emphasizing techniques based on movement and pattern. (Pieter, 2010). Sport Taekwondo was developed in the 1950’s and emphasizes speed and combination. Taekwondo combines combat and self-defense techniques with sport and exercise. It was originally based on Japanese karate using non-contact rules for competition and then eventually assembled under the International Taekwondo Federation in 1966. The full-contact version eventually emerged in Korea in 1973, under the auspices of the World Taekwondo Federation. This full-contact martial art form of taekwondo is the type that occurs in the Olympic Games (Pieter, 2010). Taekwondo was first included in the Olympic Games in 2000 (Kazemi & Pieter, 2004).

Taekwondo is characterized by its emphasis on dynamic kicking techniques delivered from a mobile stance. Taekwondo places much of its emphasis on high kicks. Eighty-percent of the competitive techniques used in taekwondo are kicks (Zetaruk et al., 2004). There are many attributes required in order to successfully compete in taekwondo including strength, speed, stamina, balance, flexibility, and coordination. Each of these skills is important to the execution of the highly dynamic kicking combinations used in

taekwondo (Kazemi & Pieter, 2004). However, a deficiency in one or all of these attributes could result in injury to the competitor. Injury to the attacker or defender can occur as a result of these highly skilled kicks. In addition to injury mechanism, injury causation may also relate to the types of sparring styles (contact, non-contact, minimal contact) being utilized by the taekwondo athlete, as well as age and skill level of the participant.

Styles of taekwondo differ based on the type of taekwondo School and sparring rules which consist of non-contact, semi-contact, and full-contact. These sparring rules are governed by the World Taekwondo Federation, and they allow full-contact sparring using kicks to the head and torso and punches to the front of the torso. Taekwondo athletes are required to wear a variety of protective gear including a trunk protector, head protector, groin protector (only in male competitors), forearm and shin guards, mouthpiece and gloves (Kazemi & Pieter, 2004).

Based on the World Taekwondo Federation's (WTF) rules (World Taekwondo Federation, 2012) there are two legal scoring areas: the body and the head. To score a point on the body, the opponent must strike the red or blue colored areas of the body protector. Scoring a point on the head requires attacking the head above the collar bone (i.e. the whole part of the head including both ears and the back of the head). Points will be awarded when permitted techniques are delivered accurately and powerfully to the legal scoring areas. One point is awarded for a valid attack on the trunk protector, two points for a valid turning kick to the trunk protector, three points for a kick to the head, and four points for a valid turning kick to the head. These scores are summed for 3 rounds during a competition.

There are only a few permitted techniques in taekwondo. The first technique is delivering a punch using the tightly clenched fist, and the second is delivering kicks using any part of the foot below the ankle bone. Only foot techniques are allowed when attacking the head. Also, attack techniques are not permitted on any part of the spine (World Taekwondo Federation, 2012).

Regardless of the strict rules and protective equipment, there is still an inherent risk of injury to the athletes, as with any contact or collision sport. For example, there are an estimated 9,300 children who present annually to emergency departments in the United States with martial arts related injuries, including taekwondo injuries (Kazemi and Pieter, 2004). Since some injuries are preventable, there must be some effort put forth to reduce the risk of these injuries from occurring. Examining the epidemiology of injury, including potential risk factors, provides the basis for a reduction of these injuries in the taekwondo population.

Although injury risk factors have been studied in taekwondo, study results are mixed. Age has been studied as a risk factor in both males and females, as well as in adult and youth competitors. However, the results of these tests have been mixed across studies. Some studies have reported sex as a risk factor for injury, while others have refuted these findings (Birrer, 1996; Beis et al., 2001; Pieter, 2002; Zetaruk et al., 2004; Pieter et al., 2010). Some studies have reported increased risk of injury for males, while some have reported increased risk of injury for females, thus results are mixed (Pieter & Zemper, 1997; Pieter et al., 2010). Body weight as an injury risk factor has not been extensively studied, or tested for significance; however, it has been suggested that

increased weight is related to an increased risk of injury (Pieter & Zemper, 1997; Beis et al., 2007).

Experience has been studied extensively as a risk factor, but the results varied from study to study (Zetaruk et al., 2004; Birrer, 1996). Kazemi et al., (2009) reported that experienced competitors appear to have an increased risk of injury due to a past history of injury, but age or gender do not seem to play a role. Due to lack of pre-injury interviews and follow-up in most studies, data on previous injury history as a risk factor are lacking (Birrer, 1996). Exposure time has been extensively studied and tested as an injury risk factor (Birrer 1996; Zetaruk et al. 2004). However, exposure time has only been reported for competition. Since there is typically more training than competition exposure time, it is important to address training exposure time and identify its impact on injury in the taekwondo athlete.

Evaluation of preventive measures depends particularly on the identification of modifiable risk factors. It is important to understand the potential risks in order to reduce the chance of injury to the taekwondo athlete.

Based on previous research, it is known that injuries are very common among taekwondo athletes, even at the elite taekwondo levels (Pieter et al., 2010; Kazemi et al., 2009). However, most research has focused on the adult competitor, with very little research conducted at the youth levels (Kazemi et al., 2009).

Exploring the extant literature on youth and adult taekwondo competitors reveals that most studies involve injuries occurring during tournaments and competitions; very few involved training. Further, most of the research does not provide a prospective

accounting of injuries sustained in training as well as competition (Pieter & Zemper, 1997; Pieter et al., 1998; Beis et al., 2001). Injury frequency during training may differ from tournaments and competitions, perhaps due to greater exposure during competition and tournaments (Caine, 2006). Competitions are typically a single contest or bout, whereas tournaments are a group of single contests or bouts over an extended period of time.

Another limitation that exists in the taekwondo literature is the common use of retrospective studies (Lystad et al., 2009). A reporting bias may be present where the injured athletes may not report injuries that occurred or even forgot about them; also athletes typically tend to remember the more serious injuries and forget the less serious ones (Caine, 2006; Lystad et al, 2009; Zetaruk et al., 2004).

Statement of the problem

The purposes of this research are: (1) to determine the incidence and distribution of injuries affecting young and adult competitive taekwondo athletes during training, competition, and tournaments; and (2) to explore the relationship between individual injury rates and the following potential risk factors: age, sex, body weight, experience, injury history, and the use of protective equipment/measures. Overall, this research will focus on the following questions related to the epidemiology of injury in taekwondo:

- Who is affected by injury?
- Where does injury occur?
- When does injury occur?
- What is the outcome of injury?

- Injury mechanisms, and
- Injury risk factors

Definitions

Injury

An injury will be defined as "any injury to a body part (as a result of training or competition in taekwondo) that interferes with training or competition and is recorded on the first day of onset and every day thereafter until it does not interfere with training or competition."

Time-Loss Injury

Time loss injury is defined as any injury that results in a competitor that is unable to take full part in future training or competition beyond the day of the injury (Lystad et al., 2008).

Overuse Injury

Overuse injury is defined any injury that occurs from repetitive microtrauma over the course of time, with no single identifiable event that caused the injury (Lystad et al., 2009).

Traumatic Injury

Traumatic injury is defined as an injury that is caused from one single, identifiable event (Lystad et al., 2009).

Recurrent Injury

Recurrent injury is defined as an injury of the same type and same location as an index injury (the first injury) and which occurs after a player's full return to participation from the index injury (Lystad et al., 2009).

Injury Severity

Injury severity is defined as how serious an injury is and will be graded on an injury severity scale: Mild (No time loss to less than a week of time loss); moderate (time loss of one week to one month); and severe (time loss more than one month) (Kazemi & Pieter, 2004).

Injury Rates

Two types of injury rates will be calculated: (1) number of injuries per 1,000 Athletic-Exposures (A-E) and (2) number of injuries per 1,000 hours of participation. An A-E is defined as one taekwondo athlete participating in one practice or one competitive event.

Anatomical Location

Data on anatomical location of injury varies across studies. Anatomical location will be defined as the specific area of the body where an injury occurs, whether it be the head, neck, spine, shoulder, elbow, upper/lower arm, wrist, hands or fingers in the upper body. The lower body will be defined as hip, upper/lower leg, knee, ankle, foot or toes. The torso will be a separate entity, separated into the thoracic and lumbar region.

Mechanism of injury

Mechanism of injury was defined as the circumstance in which an injury occurs. Mechanisms of injury can be, but are not limited to, delivering an offensive kick or punch, receiving an offensive kick or punch, using a defensive kick or punch to block an attack, an unblocked attack, falls, contact with a brick/board, or self-defense techniques.

Significance of Study

Because the sport of taekwondo has evolved in recent years and there are greater numbers of participants and injuries, the epidemiology of injury in youth and adult taekwondo has received more attention (Lystad et al., 2009; Kazemi et al., 2009). However, there are still few studies that address youth taekwondo participants and the injuries that they incur in their sport. Most of the extant literature has focused on tournament and competition injury, with very little addressing training regimens and training injury profiles. Also, much of the existing literature has been retrospective in nature so it is important that this study focuses prospectively on the incidence and distribution of the taekwondo injury during competition and training (Pieter & Zemper, 1997; Pieter et al., 1998; Beis et al., 2001).

Given the lack of conclusive research on risk factors, it will also be important to study and clarify risk factors that may potentially relate to an athlete's increased risk for injury. While age, sex, experience, and exposure have been studied and tested for significance in some studies, the results are inconsistent and need to be clarified for all levels, ages and sex.

Body weight and previous injury history also need to be studied more extensively

since data are lacking and the data that do exist are inconsistent. In order for all taekwondo athletes to compete at a safer level in the future, it is important to understand the risk and severity of injury, as well as possible risk factors. This information, in turn, can be used as a basis for identifying and testing possible preventive measures.

CHAPTER II

LITERATURE REVIEW

Introduction

Although taekwondo is becoming an increasingly popular sport, there is a lack of good epidemiological research on taekwondo injuries (Schluter-Brust, 2011). There has been a significant increase in the number of people participating in taekwondo, and as a result, injuries to this population are also expected to increase (Pieter, 2005). Although injuries are expected to increase, most of them are not serious (Pieter, 2010). Most studies conducted thus far on taekwondo injuries have combined age groups to include children and adults. Although children have been included in these studies, their data were combined with the adult data. As a result, youth injury rates have not been distinguished from the adult injury rates in the research literature (Pieter & Zemper, 1997).

It is important to review the epidemiology of youth and adult taekwondo injuries, in both competition and training, and to distinguish injury rates and characteristics between young and adult taekwondo athletes. Adult and youth injuries may be very different. For example, children may take longer to recover from concussion. Additionally, injuries that may cause ligamentous rupture in an adult may cause acute epiphyseal injury in a child. The purpose of this chapter is to review the extant literature on the distribution and determinants of taekwondo injury affecting children, youth, and

adults. Specifically, this review will focus on injury rates as well as techniques, situations, age, experience, and sex that may have an impact on incidence of injury. In addition, suggestions for injury prevention and further research will be included.

This literature review employed the PubMed, Google Scholar, and Sport Discus search engines. The search included both prospective and retrospective studies related to the epidemiology of injury in taekwondo. Key words used were "taekwondo," "injuries in youth taekwondo," "injuries in adult taekwondo" "youth injuries in taekwondo," "adult injuries in taekwondo "epidemiology of injuries in youth and adult taekwondo competitors," "martial arts injuries," "injuries in martial arts," "taekwondo injuries," "martial arts," "epidemiology of injuries in martial arts," "taekwondo" and "injury."

Hand searches of the reference lists were also conducted. The search results were also narrowed down to those articles dealing with taekwondo athletes. The final selections of articles reviewed in this literature review were 23 articles which reported on injuries in youth and adult taekwondo. They include meta-analyses, original research articles, and review chapters on taekwondo injuries, with most articles reporting on injuries sustained in tournaments and competitions.

Limitations

Most of the research involves tournaments and competitions and does not provide a prospective accounting of injuries sustained in both training and competition. The number of competition injuries may be different from that of training injuries due to differing amounts of exposure, since more time is spent in training than competition.

Another limitation that exists is the common use of retrospective studies which makes it difficult to succinctly identify injuries that occurred at the time of competition, tournament, or training. A reporting bias may be present where the injured competitors may not report injuries that occurred, or injuries may even be forgotten or neglected in the reporting forms, especially less severe injuries.

Incidence of Injury

The literature search procedures produced 14 original research studies of the epidemiology of injury in taekwondo, most of which were tournament studies. Eleven studies were prospective in nature. The three retrospective studies reported injuries relative to number of participants which does not account for exposure. One prospective study reported the injuries as time-loss injuries, which may account for the lower incidence of injury compared to other studies. The results of these studies related to injury rates are summarized in two tables. Table 1 summarizes the data on children and youth, while Table 2 summarizes the injury rate data on adults.

Perusal of the data in Table 1 shows that injury rates range from 15.13/1,000 A-E to 132.4/1,000 A-E in the youth (< 18 years old). Injury rates for males ranged from 15.13 to 108.14 injuries per 1,000 AE's; for females these rates ranged from 26.38 to 132.4 injuries per 1,000 AE's. All of the studies separated injury rates by sex, except Zetaruk (2004), who combined data for males and females. With the exception of one study (Pieter and Zemper, 1997) injury rates were higher among females than males. Table 1 also reports an injury rate per 100 athletes in all but two studies (Zetaruk, 2004; Kazemi et al., 2009); however this is a less than ideal

Table 1. Incidence of injury in youth taekwondo.

Study	Design	Data Collection Interv/Question	Duration Injury Survival	Injuries Sex	Injuries Number	Sample # Participants	Rate # of Injuries Per 100 athletes	Rate # of Injuries Per 1,000 A-E
Pieter & Zemper 1997	P	Q	3 Tourn.	M	354	3,341	10.6	58.34
				F	87	917	9.49	56.57
Pieter et al. 1998	P	Q	1 Tourn.	M	20	139	14.39	78.74
				F	7	43	16.28	97.22
Beis et al. 2001	P	Q	1 season	M	76	1,223	6.21	34.23
				F	52	767	6.78	41.27
Pieter 2002	P	Q	1 Tourn.	M	31	170	18.2	108.4
				F	18	89	20.2	132.4
Zetaruk 2004	R	Q	1 year	M/F	29	49	59.18	x
Beis et al. 2007	P	Q	1 Nat'l Champ.	M	17 time loss	1,223	2.9	15.13
				F	18 time loss	767	4.94	26.38
Kazemi et al. 2009	R	Q	9 year	M	333	447	74.5	x
				F	177	186	95.16	x

KEY: P = prospective study; R = retrospective study; x = no data; M/F = male/female; I/Q = interview/questionnaire ; Tourn.=Tournament; Nat'l Champ.=National Championship

measure of injury since exposure time is not taken into account. Also, the rates for the seasonal and yearly research yielded higher injury rates in both male and female youth than did the tournaments and competitions. The elite level of the youth national championship (Beis et al., 2007) yielded a lower injury rate than did any other study; however they only reported time loss injury. In Pieter's (2005) review, a combined injury rate of 3.4/100 participants of an estimated 3,000 young male and female taekwondo athletes competing at the national level was reported.

In the Beis et al. (2001) study of the 1994-1995 Greek National Taekwondo Championships, the junior boys and girls sustained more injuries than their older and younger counterparts in their matches (Beis et al, 2001). The females recorded higher injury rates in all matches compared to the males (Beis et al., 2001). Within the young males, junior boys recorded the highest injury rate, while the junior girls sustained the most injuries within the females (Beis et al, 2001).

A review of the data in Table 2 reveals that adult injury rates are typically lower than those reported for their younger counterparts. Adult injury rates have been reported to range from 2.43 to 79.9 injuries per 1,000 AE's. Exposure-based rates for females varied from 2.43 to 25.3 injuries per 1,000 AE's, while rates ranged from 6.85 to 79.9 injuries per 1,000 AE's for males. In contrast to the youth studies, injury rates among adults were higher for males than females.

Rates for adults at the national level were found in Kazemi and Pieter's (2004) study, with adult males having a higher injury rate (15.98/100 participants) than adult females (5.01/100 participants). Based on the data provided by Pieter et al. (2010) and

Table 2. Incidence of injury in adult taekwondo.

Study	Design	Data Collection Interv/Question	Duration Injury Survival	Injuries Sex	Injuries Number	Sample # Participants	Rate # of injuries Per 100 athletes	Rate # of njuries Per 1,000 A-E
Zemper & Pieter 1989	P	Q	1 Team Trial	M	27	48	56.3	12.74
				F	20	48	41.7	9.01
Pieter et al. 1998	P	Q	1 tourn.	M	46	139	33.1	51.3
Kazemi & Pieter 2004	P	I	1 Nat'l Champ	M	35	219	15.98	79.9
				F	5	99	5.1	25.3
Zetou et al. 2006	P	I	2 Nat'l Champ	M	182	64	284.4	x
				F	78	54	121.9	x
Beis et al. 2007	P	Q	1 Nat'l Champ	M	7 time-loss	533	1.31	6.85
				F	1 time-loss	216	0.46	2.43
Kazemi et al. 2009	R	Q	9 year	M	272	447	60.9	x
				F	106	186	56.98	x
Schluter-Brust et al. 2011	P	Q	1 survey	MF	2,164	356	607.9	x

KEY: P = prospective study; R = retrospective study; x = no data; M/F = male/female; I/Q = interview/questionnaire ; Tourn.=Tournament; Nat'l Champ.=National Championship

Zetaruk (2004), boys are at a lesser risk of incurring an injury than are men, and girls are at a lesser risk than women. However, perusal of Tables 1 and 2 shows a different picture: adults generally have lower injury rates than children and youth.

Injury Characteristics

Injury Onset

The vast majority of injuries in martial arts, including taekwondo, are acute or sudden onset in nature (Pieter, 2005). According to Pieter (2005), prior to 2005 no information is available on such factors as the frequency, duration, and intensity of training of the competitors investigated, all of which are believed to have a bearing on injury onset. In a study reported by Pieter and Zemper (1997), 1.4% and 3.5% of all injuries in boys and girls, respectively, were gradual onset. Pieter and Zemper (1997) also identified three cases of calcaneal apophysitis (9, 11, and 12 years old) as a result of repeated breaking of boards in a month prior to injury.

Similar to the youth injury onset, Zetou et al. (2006) reported more acute onset injuries than gradual onset injuries in the adults they studied. In their study, 30% of the injuries were gradual onset, and 70% were acute onset ($p<0.05$). In Zemper and Pieter's (1989) study, the overuse/gradual onset injury rate for adults was 0.45/100A-E.

Injury Location

Table 3 shows a percent comparison of location of injury in youth taekwondo. Three of the four studies in this table were prospective, while that of Pieter et al. (1998) was retrospective. Kazemi et al. (2009) did not distinguish between sexes in their study.

Table 3. A percent comparison of location of injury for males and females in youth taekwondo.

Injuries	Pieter et al., 1998		Pieter & Zemper, 1997		Beis et al., 2001		Pieter, 2002		Kazemi et al., 2009
	Female	Male	Female	Male	Female	Male	Female	Male	Male/Female
N	**7**	**20**	**87**	**354**	**52**	**76**	**18**	**31**	**891**
Head	***x***	***20***	***27.6***	***34.2***	***42.3***	***34.2***	***5.6***	***19.4***	***18.8***
Head	x	5	8.1	10.5	7.7	6.6	x	12.9	x
Face/teeth	x	10	17.2	22.9	34.6	27.6	5.6	6.5	x
Throat	x	5	2.3	0.9	x	x	x	x	x
Spine/trunk	***x***	***5***	***11.5***	***12.2***	***5.8***	***22.4***	***27.8***	***6.5***	***23.94***
Neck	x	x	2.3	2.5	x	x	x	3.2	4.38
Torso	x	x	5.8	5.7	3.9	1.3	5.6	x	9.8
Back	x	x	x	x	1.9	1.3	5.6	3.2	7.63
Hip/pelvis	x	5	1.2	1.4	x	x	16.7	x	2.13
Groin	x	x	2.3	2.5	x	19.7	x	x	x
Upper Extremity	***14.3***	***10***	***19.5***	***14.1***	***x***	***2.6***	***22.2***	***16.1***	***12.2***
Shoulder	x	5	1.2	1.1	x	x	x	x	1.57
Arm/elbow	x	x	1.2	1.4	x	x	x	x	1.23
Hand/wrist/fingers	14.3	5	17.2	11.6	x	2.6	22.2	16.1	6.85
Lower Extremity	***85.7***	***65***	***41.4***	***36.7***	***42.3***	***39.5***	***44.4***	***54.8***	***54.7***
Leg	x	5	10.3	9	3.9	1.3	x	12.9	6.17
Knee	28.6	5	6.9	6.2	5.8	2.6	x	6.5	8.42
Ankle	14.3	5	12.6	5.4	7.7	4	16.7	3.2	7.97
Foot/toes	42.9	50	11.5	16.1	25	31.6	27.8	32.3	20.54
Other	*x*	*x*	*x*	*2.8*	*x*	*1.3*	*x*	*3.2*	x

KEY: x = no data

The lower extremity was the most common site for injury for boys (36.7 – 65%), followed by the head (19.4 – 34.2%) then upper extremity (2.6 – 16.1%). For girls, the lower extremity was also the most common site for injury (41.4 – 85.7%), and was also followed by the head (5.6 – 42.3%) and upper extremity (14.3 – 22.2%). In contrast, the

Kazemi et al. (2009) study reported the spine/trunk was the second most common area of injury in the youth, with the torso then back incurring the most injuries. In Pieter's (1998) study, the girls did not suffer any injuries to the head, spine, or trunk. According to Pieter's review on taekwondo injuries (2005), in boys, the lower extremities sustain most of the injuries (36.7%-65%). However, in girls, the distribution of injury by body region is less clear.

In the lower extremity, the foot/toes were the most commonly injured body part, followed by the ankle and knee. The most common site for head injury for both boys and girls was the face/teeth, followed by the other parts of the head, with the throat incurring the fewest injuries. The most common sites for injury in the upper extremity, the third most common injured body region, were the hand, wrist, and fingers.

Pieter (2002) examined injuries in taekwondo athletes at the 1999 Canadian Junior taekwondo championships (ages 6-17 years old) and found the lower extremities was the most commonly injured region (Table 3). A study done by Pieter and Zemper (1997) found the body part which incurred the most time-loss injuries was the lower extremity (21.83/1,000A-E), followed by the head and neck (20.51/1,000A-E), upper extremities (8.81/1,000A-E), and trunk (5.52/1,000A-E). In boys, the head/neck ranked first with the lower extremities incurring the most time-loss injuries (each 21.42/1,000A-E). The rates for the lower extremities for girls were 23.41/1,000A-E and 16.91/1,000A-E for the head and neck (Pieter & Zemper, 1997). Similar to other studies, Pieter et al. (2008) found that the lower extremity was the most commonly injured body region, particularly the knee and the foot/toes, followed by the head and upper extremity for young males. For young females, Pieter et al. (2008) found the lower extremity,

particularly the knee and foot/toes, were the most commonly injured anatomical locations followed by the hand, wrist, and fingers in the upper extremity.

In the Beis et al. (2001) study on taekwondo competition injuries in young Greek athletes, junior boys experienced a significant difference in distribution of injuries among body regions, with the lower extremities (22.03/1,000A-E) injured most often. Pieter and Zemper (1997) studied injuries in Junior Olympic taekwondo athletes and found the head had an injury rate of 4.61/1,000 A-E and was the most commonly injured in boys, followed by the toes (2.47) and the ankle (4.65). Similar findings were reported for girls with the head sustaining the majority of injuries (3.25/1,000A-E) followed by the ankle (4.55). Overall, taekwondo athletes are exposed to a substantial risk of sustaining injuries during competition, in particular injuries to the lower limb (Lystad et al., 2009) and the head/neck (Pieter & Zemper, 1999).

Pieter and Zemper (1999) studied head and neck injuries in young taekwondo athletes at National and International Taekwondo tournaments where competitors were aged 6-16 years. They reported a significant difference between young male and female taekwondo athletes in total head and neck injury rate with the boys (21.42/1,000A-E) recording a higher rate than the girls (16.91/1,000A-E). The head was the most injured body part for boys and girls with reported rates of 6.10/1,000A-E and 4.55/1,000A-E, respectively.

Table 4 shows a percent comparison of location of injury in adult taekwondo. Zetou et al. (2006) did not distinguish between sexes in their study. In Table 4, all of the studies were prospective in design. The lower extremity was the most common site for injury for adult males (33.3% - 44.4%), followed by the head (22.2% - 57%) and the

upper extremity (8.6% - 22.2%). For adult females, the lower extremity was also the most common site for injury (37.3% - 100%) followed by the head (13.3% - 20%), and the upper extremity (13.3%). In Kazemi and Pieter's (2004) study, adult females did not suffer any injuries to the head, spine/trunk, or upper extremities.

Table 4. A percent comparison of location of injury for males and females in adult taekwondo.

Injuries	Zemper & Pieter, 1989		Beis et al., 2001		Kazemi & Pieter, 2004		Zetou et al., 2006	Beis et al., 2007	
	Male	Female	Males	Females	Male	Female	Males/Females	Males	Females
n	**27**	**20**	**21**	**15**	**35**	**5**	**360**	**7 time-loss**	**1 time-loss**
Head	***22.2***	***20***	***33.3***	***13.3***	***34.3***	***x***	***3.4***	***57***	***x***
Head	3.7	5	x	x	8.6	x	x	57	x
Face/teeth	11.1	5	9.6	6.7	2.9	x	x	x	x
Throat	x	x	x	x	2.9	x	x	x	x
Nose	3.7	x	14.3	6.7	8.6	x	3.4	x	x
Spine/trunk	***11.1***	***x***	***14.3***	***6.7***	***17.1***	***x***	***x***	***x***	***x***
Neck	x	x	x	x	2.9	x	x	x	x
Torso	7.4	x	x	6.7	x	x	x	x	x
Back	x	x	4.8	x	8.6	x	x	x	x
Hip/pelvis	x	2.8	x	x	2.9	x	x	x	x
Groin	x	2.8	9.5	x	2.9	x	x	x	x
Upper Extremity	***22.2***	***x***	***19.1***	***13.3***	***8.6***	***x***	***11.2***	***x***	***x***
Shoulder	x	x	x	x	x	x	x	x	x
Arm/elbow	x	x	x	x	x	x	x	x	x
Hand/wrist/fingers	22.2	x	19.1	13.3	8.6	x	11.2	x	x
Lower Extremity	***44.4***	***80***	***33.3***	***66.7***	***40***	***100***	***37.3***	***x***	***x***
Leg	11.1	20	9.5	6.7	5.7	20	x	x	x
Knee	11.1	15	4.8	13.3	x	x	13.6	x	x
Ankle	x	x	9.5	6.7	14.3	20	x	x	x
Foot/toes	18.5	40	9.5	40	11.4	60	23.7	x	x
Other	*x*	*x*	*x*	*x*	*x*	*x*	*x*	*43*	*100*

KEY: x = no data

In the lower extremity, the foot/toes was the most commonly injured anatomical location, followed by the ankle and knee for both males and females. In the head, which

was the second most commonly injured region, the face and teeth were the most frequently injured body parts, followed by the nose. In the upper extremity, the most commonly injured body parts for males and females were the hand, wrist, and fingers, with no injuries occurring to the arm, elbow or shoulder.

In a prospective study on adult taekwondo, Kazemi and Pieter (2004) reported that the lower extremities were the most commonly injured body region in men (32.0/1,000A-E), followed by the head and neck (18.3/1,000A-E), then the spine (13.8/1,000A-E). All the injuries affecting adult women involved the lower extremity, with the foot and toes incurring 60% of the injuries, followed by the ankle (20%) and the knee (20%). Beis et al. (2001) reported similar results in the adults they studied, with the lower extremities incurring a majority of the injuries in adult females (23.36/1,000A-E, p=0.003), followed by the head and the upper extremities (13.3%). In males, the lower extremities (33%) and head (33%) in males being the most commonly injured body regions, followed by the upper extremity (19.1%) and spine/trunk (14.3%).

In their meta-analysis of taekwondo injuries, Lystad et al. (2009) reported that lower limb injuries in the adult population occurred more often than injuries to other body regions. In a meta-analysis reported by Zetaruk et al. (2004), risk of head/neck, groin, and upper and lower extremity injuries are higher in taekwondo than any other martial art. Compared with ice hockey and karate, taekwondo had the highest incidence of head and/or facial injury (Hewett et al., 2005).

In an adult study conducted at the Canadian National Taekwondo Championships (Kazemi & Pieter, 2004), the head and neck were the second most commonly injured

locations in adult males and females (24.9/1,000A-E). In the Beis et al. (2007) study, 14-17-year old girls were at a higher risk of sustaining an injury to the head and neck than any other age group; however, adult females did not incur any injuries to the head or neck. Also in the Beis et al. (2007) study, adult males sustained the lowest frequency of head and neck injury, next to adult females, who did not sustain any. Head and neck injuries rank second most injured in taekwondo, according to Pieter and Zemper (1999).

Timing of Injury

In most sports, more injuries occur in training simply because the exposure to risk is greater. However, the rate of injury per unit time (e.g. minute, hour) tends to be greater in competitions and tournaments for most sports (Caine et al., 2006). Beis et al. (2001) reported that 42.1% of all injuries in Greek national taekwondo championships occurred in the first match in boys, whereas 48.1% of all injuries were sustained in the first match by girls; perhaps the narrowing of the competition field by 50% after the first round may partially explain this pattern. Also, in the Beis et al. (2001) study on match characteristics and injury, adult males sustained the highest rate of injury in the first match (10.36/1,000A-E, p=0.018). Higher rates of injury also occurred in the first match in junior boys (20.18/1,000 athlete-exposures, p = 0.010), junior girls (38.48/1,000 athlete-exposures, p = 0.007), boys (10.54/1,000 athlete-exposures, p = 0.049) and girls (12.88/1,000 athlete-exposures, p = 0.029).

Hewett et al. (2005) reported a relationship between time into taekwondo competition and increased frequency of injury. Birrer (1996) stated that the risk of injury is greater in competition than noncompetition, and the severity is typically greater as

well. In taekwondo, more injuries occurred in the first tournament match, possibly because of the varying skill levels early on in tournaments and competitions. Schutler-Brust (2011) stated that with an increase in the amount of tournament frequency, there is also an inherent increase in injury. Notably, Koh and Cassidy (2004) reported that 96% of head blows and concussions took place during single-elimination matches.

Injury Severity

Injury Type

Table 5 provides a percent comparison of injury type for boys and girls in youth taekwondo. In several separate studies, contusion was the most common injury type in taekwondo (38.2% – 60%), followed by sprains (5% – 20.6%), and strains (4.5% – 16%) (Kazemi, 2009; Lystad et al., 2009; Pieter, 2005; Pieter, 2002; Beis et al., 2001; Pieter et al., 1998; Pieter & Zemper, 1997). In youth girls, the most common injury type was also contusion (14.3% – 44.4%), followed by sprains (27.6% – 85.7%).

In junior Olympic taekwondo athletes Pieter and Zemper (1997) reported an incidence rate of 8.67/1,000A-E for contusion, fractures 5.11/1,000A-E, and sprains 4.12/1,000A-E. There were differences found in the girls; the most common type of injury was a sprain (9.75/1,000A-E), followed by contusion (7.80/1,000A-E), fracture (5.85/1,000A-E), then strain (2.60/1,000A-E). Pieter and Zemper (1999) also reported that the most common injury type occurring to the head and neck was contusion, in both boys (8.41/1,000A-E) and girls (7.80/1,000A-E).

In Pieter's 2002 study, fractures (mostly to the foot) occurred to the oldest girls (11.36/1,000A-E), boys (10.99/1,000A-E) and the 11-13 year old girls (22.73/1,000A-E).

Table 5. A percent comparison of injury type for males and females in youth taekwondo.

Study	Sex	# inj	Contusion	Spr.	Str.	Fx	Conc.	Jt Dys	Lacer.	Disloc.	Epistaxis	Other
Kazemi et al., 2009	**M/F**	904	36.25	18.9	15	7.8	5.91	7.27	2.05	1.25	1.25	4.66
Lystad et al., 2009	**M/F**	1,405	36	12.5	3.4	5.4	5.4	x	9.1	0.6	x	3
Pieter, 2002	**M**	31	38.5	19.4	16	6.5	6.5	x	6.5	x	3.2	3.2
	F	18	44.4	27.8	x	11	x	x	5.6	x	x	5.6
Beis et al., 2001	**M**	76	38.2	2.6	x	2.6	7.6	x	14.5	x	11.8	x
	F	52	44.2	x	x	x	9.6	x	15.4	1.9	13.5	1.9
Pieter et al., 1998	**M**	20	60	5	x	x	5	x	15	x	5	x
	F	7	14.3	85.7	x	x	x	x	x	x	x	x
Pieter & Zemper, 1997	**M**	354	39.3	20.6	4.5	5.7	8.8	x	5.9	0.9	3.7	8.5
	F	87	34.5	27.6	6.9	10	8.1	x	2.3	1.2	1.2	5.8

KEY: x = no data; inj=injuries; spr.=sprain; str.=strain; fx=fracture; conc.=concussion; jt dys=joint dysfunction; lacer.=laceration; disloc.=dislocation

Pieter and Zemper (1997) found similar findings in competition taekwondo with fractures resulting in 5.65% of the injuries in the boys and 5.75% of the injuries in the girls. In studies reported by Pieter and Zemper (1989) and Beis et al. (2001), fractures were the second most common injury in adult males following contusions. Zetou et al. (2006) reported 40 cases of fractures (11.2%) to the legs, arms, and fingers of adult taekwondo competitors.

Table 6 provides a percent comparison of injury type in males and females in adult taekwondo. A review of this table shows that all of studies included both males and females, and the percentage of the types of injuries reported, with the exception of contusion, were consistently greater for males than females. For males, the most common type of injury was contusion (14.3% - 63%), followed by sprains (3.7% - 30.5%) then fractures (11.2% - 14.8%). For females, the most common injury type was also contusion (46.7% - 75%), followed by sprains/strains (5% - 20%) then lacerations (6.7%).

Metacarpal fractures were found to be a common injury in taekwondo athletes and could be related to the frequent use of open hands in competition (during blocks as well as when assuming the fighting stance) instead of the use of closed fists (Pieter & Zemper, 1997). Given the frequent use of the feet in taekwondo, it is perhaps not surprising that metatarsal fractures are among the most frequently occurring injuries to the lower extremities, usually as the result of a kick. Fractures are among the serious injuries in junior taekwondo competition; however, the occurrence of growth plate injuries in their most severe form (Salter-Harris IV and V) have thus far not been reported (Pieter & Zemper, 1997).

Table 6. A percent comparison of injury type for males and females in adult taekwondo.

Study	Sex	# inj	Contusion	Spr.	Str.	Fx	Conc.	Jt Dys	Lacer.	Disloc.	Epistaxis	Other
Zemper & Pieter, 1989	M	27	63	3.7	3.7	14.8	3.7	x	3.7	x	x	3.7
	F	20	75	5	5	x	5	x	x	5	x	5
Beis et al., 2001	M	21	52.4	4.8	x	14.3	4.8	x	14.3	4.8	4.8	x
	F	15	46.7	x	x	x	x	x	6.7	6.7	6.7	x
Kazemi & Pieter, 2004	M	35	14.3	28.6	11.4	x	8.6	x	14.3	x	2.9	17.1
	F	5	60	20	20	x	x	x	x	x	x	x
Zetou et al., 2006	M/F	360	41.4	30.5	x	11.2	x	x	41.4	x	3.4	13.5
Beis et al., 2007	M	7	57	x	x	x	14.3	x	14.3	x	14.3	x
	F	1	100	x	x	x	x	x	x	x	x	x
Kazemi et al., 2009	M/F	891	36.25	18.86	14.66	7.84	5.91	7.27	2.05	1.25	1.25	4.66

KEY: x = no data; inj=injuries; spr.=sprain; str.=strain; fx=fracture; conc.=concussion; jt dys=joint dysfunction; lacer.=laceration; disloc.=dislocation

With the recent upswing of public concern regarding cerebral concussion in athletes, it is important to review what is known about concussion rates affecting taekwondo athletes. Kazemi et al. (2009) reported that concussion risk in taekwondo is two-times greater than college football, based on athletic-exposures. Pieter et al. (2010) reported that boys (<18) were more likely than men, and girls more likely than women to sustain cerebral concussions in taekwondo. However, Kazemi et al. (2009) reported concussions in adult male competitors only, noting increased force and aggression. Kazemi and Pieter (2004) also reported concussions in male competitors, with a rate of 6.9 per 1,000 A-E. Beis et al. (2007) reported junior boys (14-17 year old) and girls (11-13 year old) were at a higher risk of incurring a cerebral concussion than 11-13 year old boys. Pieter and Zemper (1999) stated the cerebral concussion ranked second to contusion in both boys and girls (5.11 and 4.55/1,000A-E, respectively). Relatively similar rates were found by Koh and Cassidy (2004) who reported a concussion incidence rate of 7.86 injuries per 1,000 A-E for competition taekwondo. Pieter (2002) reported a cerebral concussion of rate of 8.76% in males and 8.05% in females, and the oldest boys were more likely to sustain cerebral concussions (16.48/1,000A-E). Koh and Cassidy (2004) also reported 226 head blows per 1,000 A-E. With blows to the head in taekwondo that don't result in concussions, epistaxis has been found, but mostly in males (Pieter, 2005).

Catastrophic Injury

The worst case scenario of taekwondo injury is catastrophic injury. Catastrophic injuries appear to occur only infrequently in taekwondo. Pieter et al. (2010) reported one male adolescent death that occurred during training. The death of the adolescent occurred

after a roundhouse kick to the celiac plexus, possibly leading to abdominal blood loss, while sparring with a more advanced opponent. Notably, the injured athlete was not wearing any protective equipment. Birrer (1996) reported that the risk of a life-threatening injury is very small in taekwondo, approximately 1 in 500 to 600 injuries. Pieter and Zemper (2007) also reported a death by a junior Olympic taekwondo athlete that suffered from a spinning kick to the head. In an eighteen-year international survey including 15,017 participants and 41,086 injuries, Birrer (1996) reported 6 fatalities, 4 resulting from blows to the head.

Time-loss

Taekwondo is shown to have the most time-loss injuries of the other martial arts because it is full-contact (Beis et al., 2007). In taekwondo, time-loss injury rates vary in boys, anywhere from 6.16/1,000A-E (Beis et al., 2007) to 25.54/1,000A-E (Pieter & Zemper, 1997). Time-loss injury rates for adult males range from 6.85/1,000A-E to 33.56/1,000A-E (Beis et al., 2007). According to Beis et al. (2007), there is no difference in time-loss injury rates between 11-13 and 14-17 year old boys. Time-loss injury rates for females range from 9.37/1,000A-E for 11-13 year old girls (Beis et al., 2007) to 29.91/1,000A-E for national and international taekwondo athletes (Pieter & Zemper, 1997). Adult female time-loss injury rates range from 2.43/1,000A-E (Beis et al., 2007) to 23.03/1,000A-E (Pieter & Zemper, 1999).

Pieter (2005) suggests recreational female taekwondo athletes <13 years incurred a higher injury rate of more severe injuries (≥21 days) than their male counterparts of the same age, while time-loss per injury in national level boy and girl taekwondo athletes

mostly required ≤7 days away from participation (Pieter & Zemper, 1997). Adult males do not sustain more time-loss injuries than women; however they had a higher risk of getting injured (Beis et al., 2007). According to Beis et al. (2007) female juniors (14-17 years old) had a higher time-loss injury rate than their adult counterparts. However, there was no difference seen between 11-13 and 14-17 year old girls in time-loss injury rates (Beis et al., 2007).

In junior taekwondo national championships, the head had the highest time-loss injury rate for boys, and the ankle had the highest rate for girls (Pieter & Zemper, 1997). In Beis et al.'s (2007) study, the head and neck had the highest time-loss injury rate for adult males. For adult females, there were no head or neck injuries reported. However, when compared across sex, the head and neck sustained the second highest time-loss injury rate in both boys and girls (Pieter & Zemper, 1997), with the adult males incurring the highest time-loss rates to the head and neck.

Most of the time-loss per head and neck injury in young national taekwondo athletes resulted in ≤7 days away from participation (Pieter & Zemper, 1999). In the 14-17 year old age group, the boys only incurred time-loss injuries to the head and neck (Beis et al., 2007). Similar to the findings of Beis et al., Pieter and Zemper (1999) reported that only males (.66/1,000A-E) incurred serious head and neck injuries that resulted in ≥21 days away from participation. In contrast to previous studies, Pieter et al. (2010) reported that the upper and lower extremities incurred the most time-loss injuries in adults (57.1% & 40.8%, respectively).

Clinical Outcome

Research on recurrent injury in taekwondo is scanty (Pieter, 2005). However, some studies have reported re-injury rates in taekwondo. Pieter (2002) reported re-injury rates of 6.99/1,000A-E in taekwondo boys and 36.76/1,000A-E in girls. Zetou et al. (2006) reported 40% of injuries in adult women and 60% of injuries in adult men are recurrent. In the Kazemi et al. (2009) nine year retrospective study of taekwondo injuries, 11.86% of injuries were attributed to previous injury.

Injury Risk Factors

Risk factors for injury include both intrinsic and extrinsic factors. An intrinsic risk factor is an internal (within the person) factor that predisposes an athlete to injury, for example the sex of an athlete. Extrinsic risk factors refer to external factors that predispose an athlete to injury, for example exposure time. Risk factors have been studied in previous taekwondo research, however not all have not been tested for significance (e.g., belt color, technique) (Pieter, 2010). Age, sex, experience, and previous injury history are the most common intrinsic risk factors which have been tested for predictive value (Beis et al, 2001; Pieter, 2002; Zetaruk et al., 2004; Birrer 1996). Extrinsic risk factors that have been studied include protective equipment and head blows (Koh & Cassidy, 2004); however, their significance has not been tested. According to Zetaruk et al. (2004), participants who compete in taekwondo are at a higher risk of injury than those who solely participate in taekwondo training (95% CI, 1.9-7.4).

Intrinsic Risk Factors

Age

The research on age as a risk factor is inconclusive. Beis et al. (2001) reported a higher injury rate with increasing age ($p < .001$) while Pieter (2002) showed a lower injury rate with increasing age ($p < .001$) in young taekwondo athletes. Pieter and Zemper (1997) agreed with Beis et al. (2001) that there is a trend of an increase in injury with increasing age. Zetaruk et al. (2004) concurred, stating that competitors older than 18 years of age are at a higher risk of injury ($p<0.05$). However, according to Zetaruk et al. (2004), competitors under the age of 18, regardless of experience (<3 or >3 years), have less than a 1% chance of major injury, and a 5% chance of multiple injuries. They also reported older competitors (> 18 years old) have a fourfold greater risk of injury than younger competitors ($p<0.05$). The probability of major injury is also greater in older (>18 years) competitors (Zetaruk et al., 2004). In contrast, Birrer (1996) reported that younger age (12-19 years old) is associated with higher rates of injury ($p < .01$). Pieter et al. (2010) believe that there is an interaction between age and experience for time-loss injuries of ≥7 days away from practice or competition as well as multiple instances of time-loss injury. For those competitors younger than 18 years old, regardless of experience, the probability of time-loss injuries ≥ 7 days was less than 1%.

Sex

Research findings on sex as a risk factor are mixed, with few studies actually testing for statistical significance. As shown in Table 1, injury rates were consistently higher for youth females compared to youth males. However, as shown in Table 2, a contrasting picture presents for adults males and females. Zetaruk et al. (2004) and Lystad et al. (2009) reported there are not any sex differences between injury rates in males and females. Pieter and Zemper (1997) reported a higher injury rate for females

(29.91/1,000A-E) than males (25.53/1,000A-E) however, the difference was small (p=0.021). In adult competitors, males are at greater risk for sustaining time-loss injuries and cerebral concussions than females (p=0.0006) (Pieter, 2010). In Junior Olympic taekwondo athletes, girls are at a higher risk for time-loss injuries than boys (p = .021) (Pieter & Zemper, 1997). However, Birrer (1996) suggested that males may experience higher injury rates and severity than females. In the Pieter et al. (2012) study on elite competition injuries, males and females injury rates were not significantly different (p>0.02). Kazemi et al. (2009) reported that gender does not affect the risk of injury, mechanism, or location of injury.

Body Weight

It has been hypothesized that individual injury rates would increase with age in taekwondo since the athletes are expected to increase in body weight and strength with age, thus perhaps also generating more power in kicks, punches, and so forth. However, this hypothesis has not been tested for statistical significance (Pieter & Zemper, 1997). Beis et al. (2007) agreed, stating that the heavier the child, adolescent, or adult taekwondo athletes are, the more injuries they might sustain. However, there is no consistent pattern in the association between weight division and injury occurrence in adult competitors. There is, however, a trend toward increasing injury rates per 1,000 A-E with increasing weight categories for boys and girls (Pieter, 2005). Pieter (2005) also reported body weight as a potential risk factor for injury, although it was not tested for statistical significance.

Experience

Martial artists with at least three years' experience were twice as likely to sustain an injury than less experienced students in one study ($p < 0.005$) (Zetaruk et al., 2004). Zetaruk et al. (2004) also stated the combination of age and experience is a significant risk factor for injury ($p<0.0001$). Those with ≥3 years of experience were at a greater risk for time-loss injury ($p < .005$) (Pieter et al., 2010). With regards to belt color, black belt taekwondo athletes sustained significantly more multiple injuries ($p < .001$) in one study (Kazemi et al., 2009). Birrer (1996) reported that inexperience, lower belt color, and <1 year of training were associated with the highest rates and severity of injury ($p < .01$). Kazemi et al. (2009) stated that lower limb and head injuries were the most common in all groups, with no significant differences between experience groups. For colored belts and less experienced athletes, the lack of experience and control may contribute to a higher than expected injury rate ($p<0.001$) (Kazemi et al., 2009).

Head blows and concussions have been associated with young age, inexperience, and lack of blocking skills ($p<0.05$) (Koh & Cassidy, 2004). Koh and Cassidy also stated that 42% of both head blow receivers and concussed athletes reported their level of sparring was similar to that of their opponent.

Previous Injury

Previous injury in taekwondo has been infrequently studied; however it has been suggested that injury rates would be higher if there is a previous history of injury (Birrer, 1996). In an eighteen-year international study, Birrer (1996) found that re-injury risk was directly correlated ($r = 0.72$) with tournament participation, contact sparring, unfamiliar

settings, early return to training, and lack of protective gear, medical support, rehabilitation, supervision and qualified training staff. On the other hand, re-injury risk was inversely correlated (r = -0.81) to noncontact sparring, use of protective equipment, supervision, proper medical staff attendance, and rehabilitation (Birrer, 1996). Kazemi et al. (2009) found that 11.86% of injuries are attributed to previous injury (p=0.008). Interestingly, Koh and Cassidy (2004) reported that competitors who had a previous history of head blows and concussions were at a reduced risk of sustaining another head blow ($p<0.05$).

Technique

Technique has not been tested as a risk factor in taekwondo. However, injuries as a result of attacking with a kick could be related to poor technique (Pieter & Zemper, 1997). Kazemi et al. (2009) stated that an improvement in technique should decrease the athlete's risk for incurring an injury. A study on international taekwondo showed that competitors who used blocking skills were at a decreased risk of receiving a head blow or sustaining a concussion ($p<0.05$) (Koh & Cassidy, 2004).

Extrinsic Risk Factors

Exposure

It is believed that the more exposure to taekwondo training and competition the athlete has, the greater the risk of injury (Zetaruk, 2004). Zetaruk et al. (2004) reported that training more than 3 hours a week is a significant predictor of injury ($p < 0.05$). However, in an eighteen year international study, there was a significant negative correlation (r=-.67) between the number of hours practiced and the number and severity

of injuries (Birrer, 1996). Also, the cumulative risk of injury increased with length of participation (Birrer, 1996). The length of rounds should also be taken into consideration. According to Pieter and Zemper (1997), rounds for junior competitors are only 2 minutes, whereas seniors have 3 minute rounds. Also, juniors have two rounds and seniors have three rounds. The risk of injury per minute of competition is greater for juniors (Pieter & Zemper, 1997). With regards to rules, blows to the head region occur commonly since the head is a major scoring region (Koh & Cassidy, 2004)

Use of protective equipment/measures

In a study reported by Koh and Cassidy (2004) on the incidence of head blows and concussions in competition taekwondo, 98% of the participants reported they did not use a mouth guard during training or competition. The authors suggested that this may make the participant more prone for facial, oral, and/or head injury. However, they did not test this relationship statistically. Notably, in this study 50% percent of athletes receiving a head blow and 41% of concussed competitors did not receive advice regarding protection of the head/face region from their coaches (Koh & Cassidy, 2004). In taekwondo, competitors are required to wear head protection, mouth guard, chest protection, arm and shin pads, as well as a groin cup (only for male competitors) (Pieter & Zemper, 1997).

Inciting Events

Table 7 summarizes the results of studies which reported data on inciting events for injury in youth boys and girls in taekwondo. According to the data summarized in

Table 7. Inciting events for injury in males and females in youth taekwondo.

	Pieter & Zemper, 1997		Kazemi et al., 2009	Pieter & Zemper, 1999		Pieter & Zemper, 1997	
	M	**F**	**M/F**	**M**	**F**	**M**	**F**
n =	354	87	904	3,341	917	155	46
	per 1,000 A-E		%	per 1,000 A-E		per 1,000 A-E	
Unblocked attack	29.33	23.41	x	19.78	14.96	12.36	13
Attacking kick	15.66	14.3	34.7	x	x	7.58	7.15
Blocking a kick	4.94	5.85	43.9	x	x	2.64	3.9
Attacking punch	2.8	4.55	1.2	x	x	0.49	1.3
Blocking a punch	0.33	1.3	2.6	x	x	x	0.65
Receiving a blow	34.77	29.91	x	20.93	16.25	15.16	17.56
Delivering a blow	14.83	11.05	x	x	x	5.77	6.5
Fall/Impact w/ Surface	2.64	1.95	3.9	x	x	2.64	3.9
Other	2.31	3.9	x	x	x	1.32	2.63

KEY: x = no data

Table 7, the most common inciting event for injury in youth boys was receiving a blow (defender was attempting to block) (15.16 – 34.77/1,000A-E), followed by an unblocked attack (defender was not blocking) (12.36 – 29.33/1,000A-E) and attacking with a kick (7.58 – 15.66/1,000A-E). For youth girls, the most common inciting event was also receiving a blow (16.25 – 29.91/1,000A-E), followed by an unblocked attack (13 – 23.41/1,000A-E), and attacking with a kick (7.15 – 14.3/1,000A-E).

In Pieter's (2005) review on martial arts injuries, situational factors associated with pediatric martial arts injuries were mostly based on injuries sustained during competition. Attacking with a roundhouse kick or receiving it led to most injuries in taekwondo, perhaps due to it being the most common kicked used (Pieter & Zemper, 1997; Pieter, 2002). Beis et al. (2007) reported there was no difference between 11-13 year old boys, 14-17 year old boys and their adult male counterparts in injury rate for swing kicks (roundhouse kicks) compared to other techniques when compared in competition, although they reported a higher injury risk for swing kicks. In girls, 14-17 year olds tend to be injured more as a result of swing kicks. The unblocked attack was the major injury situation associated with injury for both boys (19.78/1,000A-E) and girls (14.96/1,000A-E) in a study of head and neck injuries (Pieter & Zemper, 1999). During an injury situation, the major injury mechanism was receiving a blow (20.93/1,000A-E for boys, 16.25/1,000A-E for girls). Koh and Cassidy (2004) reported that 11% of competitors in their study of head and neck injuries didn't use blocking skills, exposing the head, neck, and face for injury.

Pieter and Zemper (1997) studied injury rates in children participating in

taekwondo competition and found that juniors tended to get injured as a result of unblocked attacks, followed by attacking with a kick, then blocking a kick (Table 7). Pieter and Zemper (1997) reported that the most common situation for injury for taekwondo boys and girls was an unblocked attack (12.36/1,000A-E, 13.00/1,000A-E, respectively) followed by an attacking kick (7.58, 7.15, respectively), blocking a kick (2.64, 3.90, respectively), and falls (2.14, 2.60, respectively). The girls also suffered injuries from an attacking punch (1.3/1,000A-E). The most common mechanism for injury in taekwondo boys and girls was receiving a blow (15.16/1,000A-E, 17.56/1,000A-E, respectively) followed by delivering a blow (5.77, 6.50) and impact with the surface (2.64, 3.90). With reference to belt color, black belt athletes were more likely to suffer injuries during an offensive kick as compared to the colored belts (Kazemi et al., 2009).

Table 8 summarizes inciting events for injury in adult males and female taekwondo athletes. As shown in Table 8, the most common inciting event for adult males is attacking with a kick (2.36-71.4%), followed by receiving a blow (8.02-27.4%) and delivering a blow (3.78-16%). For adult females, the most common inciting event is attacking with a kick (3.6-33.4%), followed by delivering a blow (3.15-10.1%) then receiving a blow (3.15-5.1%). Research on inciting events for adult competitors has been very inconsistent.

The injury mechanism most often reported across all injuries was the roundhouse kick in one study (Pieter, 2002). Beis et al. (2001) had similar findings with the roundhouse kick being the main mechanism. According to Kazemi et al. (2009), females were as likely to sustain an injury from blocking an attack with a kick as from an offensive kick, while males were almost twice as likely to sustain injury while receiving a

Table 8. Inciting events for injury in males and females in adult taekwondo.

	Zemper & Pieter, 1989		Beis et al., 2007		Kazemi et al., 2009	Beis et al., 2001		Zetou et al., 2006	Kazemi & Pieter, 2004	
	Male	**Female**	**Male**	**Female**	**Male/Female**	**Male**	**Female**	**Male/Female**	**Male**	**Female**
n =	27	20	7	1	891	21	15	360	35	5
	per 100 A-E		per 1,000 A-E		% of injuries	% of injuries		% of injuries	per 1,000 A-E	
Unblocked attack	5.19	1.32	5.87	x	1.8	x	x	x	x	x
Attacking kick	2.36	3.6	x	x	34.7	71.4	33.4	x	x	x
Blocking a kick	2.83	1.35	x	x	43.9	x	x	x	x	x
Attacking punch	1.42	x	x	x	1.2	x	x	x	x	x
Blocking a punch	0.47	x	x	x	2.6	x	x	x	x	x
Receiving a blow	8.02	3.15	x	x	x	x	x	35.6	27.4	5.1
Delivering a blow	3.78	3.15	x	x	x	x	x	x	16	10.1
Fall/ Impact w/ Surface	0.47	x	x	x	3.9	x	x	x	x	x
Other/unspecified	0.94	3.15	0.98	2.43	x	28.6	66.6	64.4	36.6	10.1

KEY: x = no data

kick as compared to delivering one. Additionally, the defensive kick accounted for 43.94% of the injuries, followed by offensive kick (33.68%), then falls (3.91%). Kazemi et al. (2009) reported that the proportion of injuries suffered during a defensive kick to all injuries was significantly higher for colored belt athletes (Tables 7 & 8).

Inciting events for adult taekwondo athletes are similar to their younger counterparts. Zemper and Pieter (1989) reported that receiving a blow was the most common inciting event for adult males (8.02/100A-E), followed by an unblocked attack (5.19/100A-E) and delivering a blow (3.78/100A-E). For adult females, the most common inciting event was attacking with a kick (3.6/100A-E) followed by receiving and delivering a blow (3.15/100A-E). Beis et al. (2001) reported attacking with a kick to be the most common inciting event for males (71.4%), but for females, attacking with a kick only accounted for 33.4% of the injuries. In contrast, Zetou et al. (2006) reported the most common inciting event was receiving a blow for males and females combined (35.6%).

Suggestions for injury prevention

To date, there have been no intervention studies which have tested the effectiveness of preventive measures in taekwondo. However, injury prevention strategies which have been suggested (Pieter, 2005; Pieter & Zemper, 1997) include the following:

- proper education,
- proper training,

- advice regarding the roundhouse kicks as well as more adequate game planning,
- proper teaching of blocking skills and use of protective equipment,
- re-evaluation of the rules that allows blows to the head/face,
- head contact for children and adolescents should be outlawed in taekwondo, and perhaps not make it a major scoring region for adults,
- competitors compete with closed fists as opposed to open to help reduce fractures to the hand and fingers, and
- mouth guards should be mandatory in the taekwondo competitor to help reduce the amount of dental and orofacial injuries.

Summary

Injury rates for adult males tend to be greater than for adult females, and youth girls tend to have greater injury rates than do youth boys; however, the differences are small. The vast majority of injuries seen in taekwondo have been of acute or sudden onset, with very few chronic injuries. The most common injuries reported in the taekwondo population are contusions to the torso and legs, sprains of ligaments in the lower extremity, and strains of muscles in the lower extremity and arms. Most of the injuries reported in taekwondo occur in the first match during competition, and during the early period of training. Most injuries reported in studies occurred during competition, but may be attributed to the observation that many studies have not addressed training injuries in the determination of their overall injury rates.

The most common type of injury that is sustained in males is contusion, followed

by sprains/strains. In females, the most common injury is a sprain, followed by contusion. Time-loss injury rates in the youth taekwondo population are inconsistent. Time-loss injuries in males vary anywhere from 6.16 to 33.56/1,000 A-E. Time-loss injuries for females are not as clear. Scant data are available on catastrophic injuries in taekwondo, although the occurrence of this injury type appears to be infrequent.

There are possible intrinsic and extrinsic injury risk factors in taekwondo that may predispose an athlete to injury. Possible intrinsic risk factors include age, sex, body weight, experience, previous injury history, and technique. Possible extrinsic risk factors include exposure and use of protective equipment/measures. The research on injury risk factors has been largely inconclusive with mixed findings. Reasons for this may include diversity of different populations, rule changes, and overall lack of consistent research on risk factors and the incidence of injury. More research needs to be done to test the statistical significance of these possible risk factors.

The main injury mechanism was shown to be receiving a kick to the torso and legs, followed by receiving a punch to the head and/or torso. Some injuries can occur during an attack, but most injuries were sustained by the defender from blows received from the attacker.

Challenges for further research

There is an apparent need for more research on children and youth taekwondo injuries. More studies should include a prospective design that include exposure data and track injuries in both competition and training. Since what is known about risk factors is inconclusive, more research should be done on how they can affect injury rates in young

and adult taekwondo competitors (Pieter, 2005). Risk factors of particular interest include sex, body weight, and injury history since their effect needs to be clarified.

Future research should also include studying the effect of protective equipment on the risk of injury. Kazemi et al. (2009) proposed the need for the adoption of a standardized injury classification system to be used by all martial arts medical teams. They also suggested further risk factor research related to skill level, years of experience, and injury rates, as well as the amount of training hours, age, weight, and/or belt color. Finally, there is a need to conduct studies which test injury prevention measures.

CHAPTER III

METHOD

The purposes of this research were: (1) to determine the incidence and distribution of injuries affecting young and adult competitive taekwondo athletes during training, competition, and tournaments, and (2) to explore the relationship between injury and the following potential risk factors: age, sex, body weight, experience, previous injury history, and the use of protective equipment/measures. It will be important to examine and explain prospectively the epidemiology of taekwondo injuries affecting child, adolescent, youth (7-17 years old), and adult competitor not only during competition, but also during training. The need for information on these injuries, and their rates, is apparent due to the lack of existing research in the area. The research will investigate the following epidemiological aspects related to injury:

- Who is affected by injury?
- Where does injury occur?
- When does injury occur?
- What is the outcome of injury?
- Injury mechanisms, and
- Injury risk factors

Participants

Sixty-five taekwondo participants ages 7 years and older, including both males and females, were invited to participate in this study. All participants were members of a taekwondo club located in the Midwestern United States. Participant inclusion criteria included: participants ages 7+ years old at time of enrollment, participant consent, parental consent for minors (<17 years old), and injury-free at the time of baseline data collection. The sample is a convenience sample.

Study Design

This study employs a multi-directional design, including prospective and retrospective components, to study the incidence, distribution and risk factors related to injury sustained by children, adolescents, and adults involved in taekwondo. Baseline data were collected on all participants prior to the start of data collection. Baseline data collection included gathering questionnaire information on the following: sex, age, height, weight, years of experience, belt color, and a description of any injuries sustained in taekwondo within the last calendar year. Thereafter, participants were followed forward in time for one 12-week enrollment session from March 4th, 2013 through May 24th, 2013 to determine the incidence and distribution of injury, and possible risk factors related to injury.

Instruments and Procedures

Instruments

Descriptive Component: Study Purpose 1: to determine the incidence and distribution of injuries affecting young and adult competitive taekwondo athletes during training, competition, and tournaments.

Injury report form

An injury report form (Appendix A) was used to record descriptive data on each of the following factors: weight and belt color of the athlete, injury location, environmental location, injury type, when injury occurs, injury outcome, injury mechanism, and preventive equipment/measures. The injury report form that was used for documenting injury characteristics was obtained from Dr. Willy Pieter via electronic mail communication. This is a standard injury report form that Dr. Pieter, a well-known international authority on research related to taekwondo injuries, has used in his research (Pieter & Zemper, 1997). Injury was defined as "any injury to a body part (as a result of training or competition in taekwondo) that interferes with training or competition and is recorded on the first day of onset and every day thereafter until it does not interfere with training or competition." The injury report forms were kept by the researcher in a secure, private location at the taekwondo academy.

Analytical Component: Study Purpose 2: Additionally, this study explores the relationship between injury and the following potential risk factors: age, sex, body weight, experience, previous injury history, and the use of protective equipment/measures.

Demographic and Previous Injury history form

Prior to the start of injury surveillance, study participants were asked to fill out a

Demographic and Previous Injury History (in taekwondo only) form that describes any previous injury(s) within the last year (Appendix B). The demographic component included questions which prompted the participant to provide information on sex, age, years of taekwondo experience, rank (high vs. low), and belt color. Study participants were also asked to provide anthropometric information on present height and weight. The questions in the previous injury history report component were modified from a reporting form that was used by Dr. Pieter in his study of injuries at a Canadian National Taekwondo Championship (Kazemi and Pieter, 2004). The injury history component prompted the participant to provide information on any previous injury in taekwondo within the last 12 months including anatomical location, type of injury, time-loss, mechanism of injury, injury situation (practice vs. competition), new or recurrent injury, protective equipment, and concussion history.

Procedures

The procedures for this study are summarized below in Figure 1. Prior to injury surveillance which began March 4th, 2013, Institutional Review Board (IRB) approval at the University of North Dakota (UND) was applied for and granted as well as assent (for minors) and/or consent from the athlete and his/her legal guardian (if the participant is younger than 18 years old). The first meeting with the participants was arranged by the taekwondo academy owners, and the researcher attended every training session (except for a few due to scheduling conflicts) for the first week of the twelve-week session in order to target each of the 2 different training groups (high rank vs. low rank). The groups were assembled based on rank and weekly availability, and trained twice a week for 12 weeks. Each group was then given a packet of information and forms regarding the study,

informed consent, assent form for minors, Health Insurance Portability and Accountability Act (HIPAA) (Appendix C, D, & E, respectively), Demographic and Previous Injury History form (Appendix B). Baseline data and previous injury history were collected prior to the start of injury surveillance. Injury surveillance began March 4th, 2013 continued throughout the 12 week enrollment session until May 24th, 2013. Following the injury surveillance period, data were entered in a computer system and analyzed. The results, discussion, and conclusion sections were written between May and July 2013.

Figure 1. Timeline for baseline data collection, consent, IRB approval, injury surveillance, and analysis.

Descriptive Component: Study Purpose 1: to determine the incidence and distribution of injuries affecting young and adult competitive taekwondo athletes during training, competition, and tournaments.

Injuries that occurred at any time during training or competition were recorded on an injury reporting form (Appendix A) to document any injury encountered. Injury data collection was conducted at least every second week with each of the various training groups, to interview injured athletes and follow up on previous injuries. Each time the researcher conducted injury data collection, he targeted each specific training group based on rank (low-rank: 0-1.5 years of training, high-rank: 1.5+ years of training) and

weekly availability to systematically review each injury that occurs. Each training group had separate training times each week, so the researcher targeted each training group at least once every two weeks. If a participant sustained an injury, the researcher was notified by the participant directly or by reference to an injury log which was kept at the taekwondo academy. When the researcher was notified of or otherwise learned of a new injury, he contacted each study participant individually to record the details of the injury using the direct interview technique. This was accomplished either in person or over the telephone depending on the availability of the injured participant. Each injury that occurred was documented on a separate injury report form.

Injury Data

Injury report forms were used (Appendix A) to record all injuries that the athlete identified throughout the course of this study. Injury information was obtained via visitation and follow-up at least once every second week over the course of the study by meeting individually with the injured athletes and/or his/her guardians. If the researcher was informed by the participant or by referring to the injury report log of any new injuries an injury report form was filled out using the direct interview technique. If the athlete was unavailable the researcher contacted the athlete by phone immediately to enable completion of the injury report form.

The author is the only person who kept the injury report forms and entered the data, therefore, keeping the identity of the athletes confidential and the reporting consistent. Injuries were determined by the researcher, who is a Certified Athletic Trainer.

Analytical Component: Study Purpose 2: This study explored the relationship between injury and the following potential risk factors: age, sex, body weight, experience, previous injury history, technique, and the use of protective equipment/measures.

During this research period, data related to the above-aforementioned risk factors were gathered using a demographic and injury history form which includes questions related to age, sex, body weight, experience, rank, previous injury, and protective equipment/measures.

Table 9. Description of Variables

Variable	**Explanation**
Age	Age in years (must be 7 or older)
Sex	Male or Female
Body Weight	Preset weight class of athlete
Previous Injury History	Any previous injury sustained during taekwondo training or competition
Specific Injury History	Injury history regarding specific injuries within the previous year (if they occur)
Unrelated Injury During the Season	Having an unrelated injury during the season (if they had multiple injuries)
Level of participation	Belt color, experience
Protective Equipment/measures	Protective equipment used and preventive measure taken

Age was addressed in order to compare injury rates among the different age groups. Sex was studied in order to compare the rates between males and females. The weight classifications of the athletes were taken into account to determine if there was any relation between weight and injury risk. Previous injury history provided an

accounting of what injuries the athletes had previously sustained in taekwondo in the past 12 months. Level of participation was studied to determine if there is any relation to injury based on belt color and experience in taekwondo. This study also addressed injury rates related to the use of protective equipment and whether or not the injured participant was wearing any.

Exposure

In addition to collecting information about injury incidence the researcher also collected data on the athletes' exposure time. The exposure time for each participant was made available by accessing attendance records kept at the taekwondo club. Each time the participant attended the club, the participant received one hour of exposure time, since training lasted one hour per visit. If the participant attended any competitions, their exposure time was recorded in addition to their training exposure time. Competition time was determined by the owner of the taekwondo academy based on how long each participant was competing in taekwondo, not the amount of time they spent at the competition.

Injury history

Taekwondo athletes were asked to provide injury history in taekwondo information on the Demographic and Previous Injury History form (Appendix B) which was given to each individual athlete before the study. The questionnaire prompted the athletes to provide information about any injuries that they incurred during the past 12 months. Information provided in this questionnaire was used in the study to help determine whether previous injury history was a risk factor for new injury.

Data Analysis

Descriptive Component: Study Purpose 1: to determine the incidence and distribution of injuries affecting young and adult competitive taekwondo athletes during training, competition, and tournaments.

Two injury rates were calculated: (1) injury rate per 1,000 hours exposure (1,000 times the total number of injuries sustained divided by the total number of hours trained) and (2) injury rate per 1,000 athlete-exposures (1,000 times the total number of injuries sustained divided by the total number of athlete-exposures). One athletic-exposure worked out to be equal one hour of exposure. These same procedures were used to determine an overall injury rate, individual injury rates, an injury rate for each gender, and injury rates for training and competition. In addition, information on injury distribution (e.g. injury onset, injury location, injury type, injury onset, time-loss, injury mechanism) was calculated in terms of numbers and relative percentage of injuries. These analyses were performed using SPSS 16.0 for Windows (SPSS Inc: Chicago, IL).

Analytical Component: Study Purpose 2: Additionally, this study explores the relationship between injury and the following potential risk factors: age, sex, body weight, experience, previous injury history, technique, and the use of protective equipment/measures.

The impact of risk factors – gender, age, height, weight, experience, rank, previous injury history (having a previous injury in taekwondo within the previous 12 months), specific injury history (injury history from the previous year regarding specific injury, if re-injury occurs), and having an unrelated injury during the season (if having an

unrelated injury during the season increases risk for other unrelated injuries) and use of protective equipment – on incidence rate ratios were analyzed via Poisson regression. Because of the potential for multiple injuries in some athletes, not all injuries were treated as independent data points, thus requiring Poisson regression models to be fitted using generalized estimating equations (GEE), a technique which accounts for the correlation between injuries in the same athlete. Each risk factor was initially modeled alone in an unadjusted Poisson regression. To incorporate correlations between the risk factors, adjusted incidence rate ratios (and associated 95% confidence intervals) were estimated from multiple Poisson regression. The Poisson regression analyses were performed in R (R Core Team 2012). Any risk factor with a p-value <0.05 was considered significant.

CHAPTER IV

RESULTS

Descriptive Results

Demographic Information

Baseline data collection began on March 5th, 2013, prior to the start of the Spring taekwondo session. At that time there were 65 taekwondo competitors, youth and adults, who were asked to participate in this study. However, only 24 participants decided to participate. Two subjects dropped out after informed consent was obtained, but did not participate in any capacity during the spring session (i.e., no time exposed to risk of injury). Participants (n= 22), participated in a 12-week taekwondo season, with training at least 2.5 hours per week. Six participants attended 1 competition.

Those interested in participating were asked to complete a Demographic Information and Injury History form that asked about any taekwondo injuries within the past 12 months. Table 10 summarizes the participant's demographic information. Of the twenty-two participants who agreed to participate, 14 were male (63.6%) and 8 were female (36.4%), with an overall mean age of 26.18 years (SD = 13.96 years). Of the twenty-two participants, there were 7 youth (<18 years) competitors, including 5 boys and 2 girls. There were 9 black belts (40.1% of total participants), 3 red (13.6%), 4 brown (18.2%), 1 blue (4.5%), 1 purple (4.5%), 1 orange (4.5%), and 3 white (13.6%).

Additional demographic information obtained included age of the participants, years of taekwondo experience, and number of competitions entered over the course of

data collection. As shown in Table 10 mean taekwondo experience was almost equal in male and females (M=4.67 and M=4.69 years, respectively). The mean age for males (M=25.93 years) and females (M =26.63) were also similar. The males were generally taller than the females (M =66.14 and M =62.63 inches, respectively), but the women tended to weigh more than the males, on average (M =163.88 and M =159.07 lbs, respectively). Three males and three females participated in competitions, and they were all in the adult (>18 years old) age group.

Table 10. Comparison of Participants Demographic Information by Means*

Variable	Male	Female	Total
Number	14	8	22
Age (years)	25.93 [7-49]	26.63 [9-53]	26.18 [7-53]
Youth (<18 yrs. old)	11.2 [7-16]	11 [9-13]	11.14 [7-16]
Adult (>18 yrs. old)	34.11 [19-49]	31.83 [20-53]	33.2 [19-53]
Height (inches)	66.14 [51-73]	62.63 [50-68]	64.86 [50-73]
Weight (lbs.)	159.07 [48-310]	163.88 [80-292]	160.82 [48-310]
Years of taekwondo experience	4.67 [0.33-15]	4.69 [0-20]	4.67 [0-20]
# of Low Rank (<1.5 yrs. experience)	2	1	3
# of High rank (>1.5 yrs. experience)	12	7	19
# of Competitions	3	3	6

*Mean values are noted with ranges in brackets

Injury History

In addition to demographic information, information on medical history of taekwondo-related injuries from the past 12 months was obtained. Seven of the 22 (31.81%) taekwondo participants, including 5 male and 2 female adults, reported a total of 18 injuries sustained during the 12 months prior to completing the questionnaire. Sixteen injuries were sustained by the adult males and two injuries were sustained by the adult females, while no youth were injured during the preceding year. A percent distribution of anatomical location of these pre-season (one year) injuries is provided in Table 11. The most commonly injured anatomical locations were the knee, accounting for 5 (27.8%) injuries, and the wrist with 4 injuries (22.2%).

Table 11. History of Injury
A Percent Distribution by Anatomical Location

Location	Total N of Injuries	% of Total Injuries
Jaw	1	5.6
Shoulder	1	5.6
Wrist	4	22.2
Hand	2	11.1
Knee	5	27.8
Lower Leg	2	11.1
Foot	3	16.7
Total	18	100

A percent distribution of injuries by injury type for pre-season injuries is provided in Table 12 below. As shown, the most common type of injury was inflammation (mostly

to the knees), accounting for 22.2% of the pre-season injuries, perhaps from overuse in taekwondo, followed by cartilage damage (knee meniscus and shoulder labrum) with 2 injuries (11.1%), dislocation (fingers and jaw) accounting for 2 injuries (11.1%), and contusions, hyperextensions, and abrasions all accounting for 2 injuries each (11.1%, respectively).

Table 12. History of Injury (n=7 subjects)
A Percent Distribution by Injury Type

Injury Type	N of Injuries	% of injuries
Cartilage Damage	2	11.1
Fracture	1	5.6
Inflammation	4	22.2
Dislocation	2	11.1
Contusion	2	11.1
Hyperextension	2	11.1
Ligament Sprain	1	5.6
Nerve Injury	1	5.6
Laceration	1	5.6
Abrasion	2	11.1
Total	18	100

Injury Rates

The prospective portion of this study began on March 5th, 2013, which was the beginning of this Spring taekwondo season. During the study period (3/5/2013-5/24/13), exposure data were accessed and recorded from taekwondo attendance records. From these data, the researcher was able to determine the number of athletic-exposures (AEs) and exposure hours accumulated by each participant during the season. These data, in

turn, were used as a basis for determining individual and overall injury rates. The exposure and injury data are summarized in Table 13.

As shown in Table 13, nine of the 22 participants (40.9%) sustained a total of 16 injuries during the study period. Of the 16 injuries sustained, 10 injuries were incurred by 5 male taekwondo participants and 6 injuries were incurred by 4 female taekwondo participants, all of whom were adult (i.e., older than 18 years old). Thirteen participants (59.1%) did not sustain any injuries during the season, 7 of whom were younger than 18 years old. Four participants (18.2%) sustained 1 injury, three participants (13.6%) sustained 2 injuries, and two participants (9.1%) sustained 3 injuries. Notably, none of the youth sustained an injury during the study period.

Examination of Table 13 reveals that there were a total of 459 athletic-exposures and 459 hours of exposure (since 1 A-E amounted to 1 hour of exposure) accumulated by the 22 taekwondo participants. Of the 459 athletic-exposures, training accounted for 447 AEs and competition accounted for 12 AEs.

Table 13. Overall Exposure and Injury Rate Data

Subjects	n	No. of Injuries	AE's	Rate per 1000 AE's	95% CI (low/high)	Hours	Rate per 1000 Hours	95% CI (low/high)
Adult Male	9	10	146	68.49	68.3, 68.6	146	68.49	68.3, 68.6
Youth Males	5	0	108	0	-	108	0	-
Overall Males	**14**	**10**	**254**	**39.37**	**39.3, 39.4**	**254**	**39.37**	**39.3, 39.4**
Adult Female	6	6	169	35.50	35.4, 35.6	169	35.50	35.4, 35.6
Youth Female	2	0	36	0	-	36	0	-
Overall Females	**8**	**6**	**205**	**29.27**	**29.2, 29.3**	**205**	**29.27**	**29.2, 29.3**
Overall	**22**	**16**	**459**	**34.86**	**34.8, 34.9**	**459**	**34.86**	**34.8, 34.9**

AEs = Athlete Exposures (one TKD athlete participating in one training session or competition)

Two different injury rates were calculated. The overall injury rates were 34.86 injuries per 1,000 athletic-exposures and 34.86 injuries per 1,000 exposure hours. Table 14 shows competition versus training injury rates for both males and females. Four participants incurred 5 injuries during 12 AEs of competition. Seven participants incurred 11 injuries during 447 hours of training exposure time (also 447 AEs). The competition injury rate for athletic exposures was 416.67 injuries per 1,000 athletic-exposures. The training injury rates were 24.61 injuries per 1,000 athletic-exposures, and 24.61 injuries per 1,000 exposure hours. Males had a higher overall injury rate (39.37/1,000A-E) than the females (29.27/1,000A-E), but this difference was not significant (p=0.6011). The males also had a higher training injury rate than did the females, but this was not significant (32.26 vs. 15.08/1,000A-E, respectively). However, the females incurred a higher injury rate in competition than did the males, although both were extremely high (500 vs. 333.3/1,000A-E, respectively). The youth participants, both boys and girls, had an injury rate of 0 per 1,000 athletic-exposures, but only in training since no participants under the age of 18 competed. The boys accumulated 108 athletic-exposures and 108 hours of exposure while the girls accumulated 36 athletic-exposures and 36 hours of exposure.

Injury Location

Table 15 displays a percent comparison of injuries by anatomical location and gender. The most common locations of injury were the hand/fingers accounting for 4 injuries (25%), and forearm/wrist, elbow, knee, and shoulder accounting for 2 injuries each (12.5%). The most common location of injury for the male participants was the hand/fingers (40%) and the shoulder for the female participants (33.33%).

Table 14. Exposure and Injury Rate Data
Training vs. Competition

Subjects	n	No. of Injuries	AE's	Rate per 1000 AE's	95% CI (low/high)	Hours	Rate per 1000 Hours	95% CI (low/high)
Training Adult Males	9	8	140	57.14	57.09, 57.19	140	57.14	57.09, 57.19
Training Youth Males	5	0	108	0	-	108	0	-
Training Males Overall	**14**	**8**	**248**	**32.26**	**32.17, 32.3**	**248**	**32.26**	**32.17, 32.3**
Training Adult Females	6	3	163	18.4	18.37, 18.43	163	18.4	18.37, 18.43
Training Youth Females	2	0	36	0	-	36	0	-
Training Females Overall	**8**	**3**	**199**	**15.08**	**14.8, 15.10**	**199**	**15.08**	**14.8, 15.10**
Training Overall	**22**	**11**	**447**	**24.61**	**24.59, 24.63**	**447**	**24.61**	**24.59, 24.63**
Competition Adult Male*	3	2	6	333.33	333.31, 333.4	6	333.33	333.31, 333.4
Competition Adult Female*	3	3	6	500	499.9, 500.02	6	500	499.9, 500.02
Competition Overall	**6**	**5**	**12**	**416.67**	**416.2, 417.2**	**12**	**416.67**	**416.2, 417.2**

AEs = Athlete Exposures (one TKD athlete participating in one training session or one hour of competition)

*No minors (<18 years old) participated in any competitions, so no injury rates and exposure time were not reported.

Table 15. A Percent Comparison by Anatomical Location

Location	Overall		Males		Females	
	N	%	N	%	N	%
Nose	1	6.25	1	10	0	0
Shoulder	2	12.5	0	0	2	33.33
Elbow	2	12.5	1	10	1	16.67
Forearm/Wrist	2	12.5	1	10	1	16.67
Hand/Fingers	4	25	4	40	0	0
Lower Back	1	6.25	1	10	0	0
Knee	2	12.5	1	10	1	16.67
Lower Leg	1	6.25	0	0	1	16.67
Foot	1	6.25	1	10	0	0
Total	16	100	10	100	6	100

Injury Type

A percent comparison of the specific type of injury sustained by the participants in this study is shown in Table 16. The most common type of injury was contusion, primarily to the hand, wrist, forearm, and knee, which accounted for 4 injuries (25%). The second most common injury sustained was laceration, primarily to the fingers, hand, and foot, which accounted for 3 injuries (18.75%). Other, less common injuries were muscle strains to the low back and lower leg and dislocations of the finger and elbow, accounting for two injuries each (12.5%).

Table 16. A Percent Comparison by Injury Type

Injury Type	Overall		Males		Females	
	N	%	N	%	N	%
Laceration	**3**	**18.75**	**3**	**30**	**0**	**0**
Finger	1	6.25	1	10	0	0
Hand	1	6.25	1	10	0	0
Foot	1	6.25	1	10	0	0
Contusion	**4**	**25**	**3**	**30**	**1**	**16.67**
Hand	1	6.25	1	10	0	0
Wrist	1	6.25	0	0	1	16.67
Forearm	1	6.25	1	10	0	0
Knee	1	6.25	1	10	0	0
Strain	**2**	**12.5**	**1**	**10**	**1**	**16.67**
Low Back Strain	1	6.25	1	10	0	0
Calf Strain	1	6.25	0	0	1	16.67
Hyperextension	**1**	**6.25**	**0**	**0**	**1**	**16.67**
Elbow	1	6.25	0	0	1	16.67
Dislocation	**2**	**12.5**	**2**	**20**	**0**	**0**
Finger	1	6.25	1	10	0	0
Elbow	1	6.25	1	10	0	0
Shoulder Labrum Tear	**1**	**6.25**	**0**	**0**	**1**	**16.67**
Shoulder Subluxation	**1**	**6.25**	**0**	**0**	**1**	**16.67**
Sprain	**1**	**6.25**	**0**	**0**	**1**	**16.67**
MCL	1	6.25	0	0	1	16.67
Epistaxis	**1**	**6.25**	**1**	**10**	**0**	**0**
Total	16	100	10	100	6	100

Table 16 also shows a percent comparison of injury type by gender. The most common injury types for male participants were contusions accounting for 3 injuries (30%) and lacerations accounting for 3 injuries (30%), followed by dislocations which accounted for 2 injuries (20%). The females sustained a variety of injury type, including contusion and muscle strain which were common to males.

Injury Onset

Injury onset is typically divided into two categories: acute and chronic/overuse. Acute injuries are the only injuries that occurred during data collection.

Injury Classification

Injury classification was used to differentiate if the injury was a new injury or if the taekwondo competitor had previously experienced a similar injury. The three categories that were used to classify an injury were: (1) new injury, (2) recurrence of taekwondo injury from this season, and (3) recurrence of taekwondo injury from previous season. For the purpose of this study, recurrence of injury was defined as an injury of the same type and same location as the initial injury and which occurs after a participant's full return to participation from the initial injury. However, in many cases a re-injury is more severe than the first injury, as determined by time loss.

The most common classification was new injury, accounting for 13 of the 16 injuries (81.25%). Of those 13 injuries, 4 were sustained by females and 9 were sustained by males. The second most common classification was recurrence of injury from previous season accounting for 2 injuries (12.5%), and recurrence of injury from this season accounted for 1 injury (6.25%).

Timing of Injury

As shown in Table 17, the most common timing for an injury to occur was in the second-half of training accounting for 6 injuries (37.5%), and followed by the second-half of competition accounting for 5 injuries (31.25%). For males, the most common timing for an injury to occur was in the second-half of training accounting for 5 injuries (50%), followed by the second-half of competition accounting for 3 injuries (30%). For females, the most common timing for an injury to occur was the first-half of training accounting for 3 injuries (50%), followed by the second-half of competition accounting for 2 injuries (33.33%).

Table 17. A Percent Comparison of Injury Timing

Timing	Overall		Males		Females	
	N	%	N	%	N	%
Training	**11**	**68.75**	**7**	**70**	**4**	**66.67**
First ½	5	31.25	2	20	3	50
Second ½	6	37.5	5	50	1	16.67
Competition	**5**	**31.25**	**3**	**30**	**2**	**33.33**
First ½	0	0	0	0	0	0
Second ½	5	31.25	3	30	2	33.33
Total	16	100	10	100	6	100

Injury Situation

During the study period, injuries occurred in a variety of situations. Table 18 displays a percent comparison of the different injury situations in which injury occurred. The two most common situations for injury were blocking a kick accounting for 5 injuries (31.25%) and brick/board breaks accounting for 5 injuries (31.25%) followed by drills (2 injuries, 12.5%) in which the participant was working on movement patterns or

working with a partner (but not sparring). A technique in which a participant was put in a bear hug and attempted to escape accounted for 2 injuries as well (12.5%). The remaining injury situations included fall and a self-defense hold, each accounting for one injury. Similarly, the most common injury situations for males were blocking a kick and brick/board breaks, each accounting for 3 injuries (30%). The most common injury situations for females were also blocking a kick and brick/board breaks, each accounting for 2 injuries (33.33%).

Table 18. A Percent Comparison of Injury Situation

Injury Situation	Overall		Males		Females	
	N	%	N	%	N	%
Blocking a kick	5	31.25	3	30	2	33.33
Drills	2	12.5	1	10	1	16.67
Fall	1	6.25	1	10	0	0
Brick/Board Breaks	5	31.25	3	30	2	33.33
Bear Hug Technique	2	12.5	2	20	0	0
Self-Defense Hold	1	6.25	0	0	1	16.67
Total	16	100	10	100	6	100

Mechanism of Injury

Over the course of this study, there were five distinct injury mechanisms that resulted in the 16 total injuries. A category labeled “no evidence of contact” was included for those injuries that did not occur as a result of contact with the floor, brick, board, or opponent. Table 19 displays a percent comparison of mechanism of injury for both male and female participants. The most common mechanism was impact with a surface accounting for 6 of the 16 injuries (37.5%), followed by receiving a blow which accounted for 5 injuries (31.25%). For male participants, the most common mechanism was impact with a surface accounting for 4 injuries (40%). Notably, 3 of these 4 injuries

resulted from contact with a board. In contrast, the most common injury mechanisms affecting female participants were receiving a blow and impact with a surface accounting for 2 injuries each (33.33%). There was one male injury from an impact with the surface after falling, one female injury from impact during a board break and another female injury from impact during a brick break.

Table 19. A Percent Comparison of Mechanism of Injury (MOI)

MOI	Overall		Males		Females	
	N	%	N	%	N	%
Receiving a blow	5	31.25	3	30	2	33.33
Impact w/ surface (floor, brick, board)	6	37.5	4	40	2	33.33
Self-Defense hold	1	6.25	0	0	1	16.67
Hand Pulled by opponent	1	6.25	1	10	0	0
Finger pulled by opponent	1	6.25	1	10	0	0
No evidence of contact	2	12.5	1	10	1	16.67
Total	16	100	10	100	6	100

Time Loss

For this study, time loss was calculated based on the number of training sessions that the participant missed completely or did not participate in fully because of an injury. All of the injuries sustained in this study are classified as “mild”, resulting in <7 days away from taekwondo. In fact, all of the injuries, except one, required no time off from taekwondo. One injury in a female participant required 2 days off from taekwondo training after suffering from a hyperextension of the elbow during training, which would be graded as a mild injury as well.

Male subjects who sustained an injury during competition or training did not discontinue training or stop competing at all after the injury. However, among females,

only one participant discontinued training on the day of injury and for two training days after hyperextension of the elbow joint.

Risk Factor Data Analysis

Risk factors of interest in this study included sex, age, height, weight, experience, rank [high (>1.5 years of taekwondo experience) vs. low (<1.5 years of taekwondo experience)], a history of injury to any body part, specific injury history, and having an unrelated injury during the study. These risk factors were analyzed in both unadjusted (risk factors analyzed alone) and adjusted (risk factors analyzed with others) Poisson regression models that were fitted using generalized estimating equations. Incidence Rate Ratios (IRRs) were provided for the unadjusted (univariate analyses) and adjusted (i.e., multivariate analyses) risk factors. Any risk factors that had a *p*-value of <0.05 were considered statistically significant.

Table 20 shows both the unadjusted and adjusted results of the regression analyses and identifies the injury rate ratio per 1,000 athletic-exposures and per 1,000 hours of exposure for each risk factor. Age (IRR=0.064; CI=0.037, 0.091), height (IRR=0.113; CI=0.056, 0.170), weight (IRR=0.009; CI=0.005, 0.013), and having an injury specific history (IRR=0.767; CI=0.179, 1.356), were all significantly associated with a reduction in risk of injury (95% CI, $p<0.05$) in the univariate analyses, before adjusting for the other risk factors. Analyses for years of experience, gender, and rank (high vs. low) resulted in a non-significant effect. Previous injury history (IRR=1.08; CI=0.158, 2.002) and having an unrelated injury during the season (IRR=1.231; CI=0.680, 1.783) were associated with a slight, significant increased risk of injury (95%

CI, $p<0.05$). Injury specific history was associated with a significant decreased risk of injury (IRR=0.767, 95% CI=0.179, 1.356).

Because of the relatively large number of variables and small population size in this study, multivariate analyses could not be run on all variables. For the adjusted rate ratios, a multiple Poisson-regression was run using four risk factors: sex, weight, having a history of previous injury, and having an unrelated injury during the season. After adjusting for the other factors, sex and previous injury history were no longer significant risk ($p>0.05$). However, weight was significantly associated with a reduction in risk of injury (IRR=0.005, 95% CI=0.002, 0.009). Additionally, having an unrelated injury during the season was also significantly associated with a reduction in risk of injury in the multivariate analyses (IRR=0.655, 95% CI=0.505, 1.198).

Table 20. Risk Factors Analysis of Incidence Rate Ratios (IRRs) per 1000 AEs

	Unadjusted			Adjusted		
Risk Factor	IRRs	95% CI	P Value	IRRs	95% CI	P Value
Gender			0.6131			0.6011
Female	Referent			Referent		
Male	0.247	-0.711, 1.205		-0.211	-1.001, 0.580	
Age	0.064	0.037, 0.091	<0.0001			
Height	0.113	0.056, 0.170	<0.0001			
Weight	0.009	0.005, 0.013	<0.0001	0.005	0.002, 0.009	0.0029
Experience	0.026	-0.020, 0.071	0.2708			
Rank			0.1210			
Low	Referent					
High	1.330	-0.351, 3.010				
Previous Injury History			0.0217			0.1211
No	Referent			Referent		
Yes	1.080	0.158, 2.002		0.686	-0.181, 1.553	
Specific Injury History			0.0106			
No	Referent					
Yes	0.767	0.179, 1.356				
Unrelated Injury during Season			<0.0001			0.0180
No	Referent			Referent		
Yes	1.231	0.680, 1.783		0.655	0.505, 1.198	

CHAPTER V

DISCUSSION

Descriptive Analysis

Demographic Information

The study population for this project was a convenience sample from the Midwestern region of the United States. Although 65 athletes were invited, only 22 agreed to participate. Many invitees may have elected not participate due to the lengthy paperwork, and may have not wanted the burden of keeping track of injuries. Also, with regards to minors, it is possible that guardians did not receive or otherwise chose not to sign the permission form.

Participants for this study included both males and females and children and adults in order to better understand the epidemiology of injury related to age groups and sexes. The participants in this study competed under the auspices of the World Taekwondo Federation, which consists of more sparring and more demanding movements than the American Taekwondo Association, thus making it more of a physically demanding sport. Yet, the sample was primarily recreational in nature given that only 6 of twenty-two participants entered a competition during the study period. The population size for this study was typically smaller than what has been seen in taekwondo injury research (range = 96-749 participants), potentially limiting generalization of the results. The average age of this study population for males was 25.93 years and 26.63 years for females, which was higher than what has been reported in other studies (Kazemi

et al., 2009; Zetou et al., 2006; Kazemi & Pieter, 2004), in which the average age was typically in the low twenties.

Nineteen of the 22 participants had more than 1.5 years of experience and up to 20 years of experience. The average years of taekwondo experience was 4.67 years, which is seemingly likely to be less than elite levels, but difficult to compare nonetheless. There has been a considerable body of research published on experienced taekwondo competitors, thus this research study can adequately contribute to the existing research by providing injury data on a mostly recreational group. Previous history of taekwondo injury can play a role in future injury. During the 12 months prior to the start of this study, seven of the 22 participants (31.81%) sustained an injury in taekwondo.

Injury Rate

Table 21 shows a comparison of injury rates between this and previously published studies of taekwondo-related injuries. Compared to the other studies in Table 21, the injury rates per 1,000 athletic-exposures for this study were typically higher. Kazemi et al. (2004) and Pieter et al. (1998) reported higher injury rates for adult males (79.9 & 51.3/1,000A-E, respectively) than did this study, which had an adult male injury rate of 68.49 per 1,000 AEs. The injury rate for adult females in this study was 35.50 per 1,000 AEs, which was the highest among the published studies. Kazemi and Pieter (2004) reported a lower injury rate in adult females (25.3/1,000A-E) compared to this study. The relatively high rates of injury reported in this study may be an artifact of the relatively small sample size. It may also reflect the use of the direct interview technique used to

Table 21. Overall Injury Rates in Adult Taekwondo

Study	Design	Data Collection	Duration	Injuries		Sample #	Rate # of injuries	Rate # of njuries	Rate # of injuries
		Interv/Question	Injury Survival	Sex	Number	Participants	Per 100 athletes	Per 1,000 A-E	Per 1,000 hours
Zemper & Pieter 1989	P	Q	1 Team Trial	M	27	48	56.3	12.74	x
				F	20	48	41.7	9.01	x
Pieter et al. 1998	P	Q	1 tourn.	M	46	139	33.1	51.3	x
Kazemi & Pieter 2004	P	I	1 Nat'l Champ	M	35	219	15.98	79.9	x
				F	5	99	5.1	25.3	x
Zetou et al. 2006	P	I	2 Nat'l Champ	M	182	64	284.4	x	x
				F	78	54	121.9	x	x
Beis et al. 2007	P	Q	1 Nat'l Champ	M	7 time-loss	533	1.31	6.85	x
				F	1 time-loss	216	0.46	2.43	x
Kazemi et al. 2009	R	Q	9 year	M	272	447	60.9	x	x
				F	106	186	56.98	x	x
Schluter-Brust et al. 2011	P	Q	1 survey	MF	2,164	356	607.9	x	x x
THIS STUDY 2013	P	I/Q	2 ¾ mo. Train/Comp.	M	10	14	71.43	68.49	68.49
				F	6	8	75	35.5	35.5

KEY: P = prospective study; R = retrospective study; x = no data; M/F = male/female; I/Q = interview/questionnaire

gather data on injuries. Notably, the two other studies that used the interview as a means of data collection (Kazemi and Pieter, 2004; Zetou et al., 2006) also had relatively high rates of injury. Furthermore, the use of a Certified Athletic Trainer to collect data may have also influenced the differences in injury rates reported.

For overall injury rates, this study had an injury rate of 34.86 per 1,000 AEs with the genders and ages combined. Schutler-Brust et al. (2011) reported a combined injury rate of 607.9 per 100 participants, which is higher than the clinical incidence rate reported in this study (i.e., 72.72 per 100 participants). However, when looking at rates per 100 athletes, it is difficult to compare across studies since exposure time is not taken into account.

Previously published studies generally report only competition injury rates, but this study reported injury rates for both training and competition. The overall injury rate for adult competition in this study was 416.67 per 1,000 AEs, which is much higher than other reported rates. The competition injury rate for adult males was 333.33 per 1,000 AEs and 500 injuries per 1,000 AEs for adult females; again, the highest of the published studies. These differences may relate, however, to the small number of subjects in this study who participated in a competition. The training injury rate for adult males was 57.14 injuries per 1,000 AEs and was 18.40 per 1,000 AEs for adult females.

In most sports, there are more injuries that occur in training than competition simply because the participant's exposure to risk of injury is greater in training. However, when incidence rates are calculated the rate of injury is typically greater in competition than training because sparring intensifies and it becomes more full-contact than during training.

Injury rates for children tend to be higher than for adults (Chapter 2, Table 1). Injury rates for boys range from 34.23 to 108.4 per 1,000 AEs, and from 41.27 to 132.4 per 1,000 AEs for girls. However, in this study there were only 7 participants under the age of 18, 5 boys and 2 girls, none of whom were injured (0/1,000A-E) during the study period. So compared to previous research, the injury rates for the youth participants in this study are much lower. This finding may reflect the small sample size of children and relatively short period of surveillance in this study. Additionally, children tend not be as strong as adults, and therefore not as able to strike as forcefully as their older counterparts, possibly reducing the likelihood for injury.

In addition to taekwondo-related research, Zetaruk et al. (2004) studied the injury rate in other martial art styles. The styles included karate, kung fu, tai chi, and aikido. Table 22 shows a comparison of clinical incidence rates and the clinical incidence rate from this study. This study had the highest injury rate per 100 participants (72.72) of the other 4 styles shown in the table. Aikido had the second highest injury rate, which was 51.06 injuries per 100 participants, followed by kung fu (38.46) and karate (29.82).

Table 22. A Comparison of Injury Rates by Style

Style	Number of Participants	Number of Injuries	Injury Rate Per 100 participants
THIS STUDY	22	16	72.72
Karate*	114	34	29.82
Kung Fu*	39	15	38.46
Tai Chi*	14	2	14.28
Aikido*	24	47	51.06

*Information provided by Zetaruk et al., 2004.

Zetaruk et al. (2004) reported that taekwondo typically has a higher injury rate, although martial arts in general tend to be relatively safe for beginner and intermediate

levels. The higher injury rate in taekwondo may also be explained by the quick, powerful striking maneuvers, while striking patterns and maneuvers differ amongst the other styles (Zetaruk et al., 2004). Nonetheless, these comparisons should be interpreted with caution given that clinical incidence rates do not accommodate for the variable exposure time of participants to risk of injury.

Injury Location

Table 23 shows the percent comparison of injuries by anatomical location for previously published studies and this study. Other studies (Zemper & Pieter, 1989; Beis et al., 2001; Kazemi & Pieter, 2004; Zetou et al., 2006) reported the lower extremities as the most commonly injured body region, but this study reported the upper extremity as the most injured body region. The percentage of upper body injuries was 60 percent for males and 66.67 percent for females. The percent range for male upper extremity injuries in males in the published studies was from 8.6 to 22.2 percent, or lower than the injuries in this study (60%). Only one published study reported proportion of upper extremity injuries in females. Beis et al. (2001) reported that upper extremity injuries accounted for 13.3 percent of all injuries in their study; whereas females in the present study incurred 66.67 percent of total female injuries to the upper extremity. This difference may be explained by the primarily recreational nature of the competitors, and their inexperience in utilizing the upper extremities effectively in taekwondo, unlike their elite counterparts.

The second most common body region to sustain injuries in this study was the lower extremity. Males sustained 20 percent of their injuries in the lower extremities; the range in the published studies being 33.3 percent to 44.4 percent for the lower extremity,

Table 23. A percent comparison of location of injury for adult males and females in taekwondo

Injuries	Zemper & Pieter, 1989		Beis et al., 2001		Kazemi & Pieter, 2004		Zetou et al., 2006	Beis et al., 2007		THIS STUDY 2013	
	Male	Female	Males	Females	Male	Female	Males/Females	Males	Females	Males	Females
n	**27**	**20**	**21**	**15**	**35**	**5**	**360**	**7 time-loss**	**1 time-loss**	**10**	**6**
Head	***22.2***	***20***	***33.3***	***13.3***	***34.3***	***x***	***3.4***	***57***	***x***	***10***	***x***
Head	3.7	5	x	x	8.6	x	x	57	x	x	x
Face/teeth	11.1	5	9.6	6.7	2.9	x	x	x	x	x	x
Throat	x	x	x	x	2.9	x	x	x	x	x	x
Nose	3.7	x	14.3	6.7	8.6	x	3.4	x	x	10	x
Spine/trunk	***11.1***	***x***	***14.3***	***6.7***	***17.1***	***x***	***x***	***x***	***x***	***10***	***x***
Neck	x	x	x	x	2.9	x	x	x	x	x	x
Torso	7.4	x	x	6.7	x	x	x	x	x	x	x
Back	x	x	4.8	x	8.6	x	x	x	x	10	x
Hip/pelvis	x	2.8	x	x	2.9	x	x	x	x	x	x
Groin	x	2.8	9.5	x	2.9	x	x	x	x	x	x
Upper Extremity	***22.2***	***x***	***19.1***	***13.3***	***8.6***	***x***	***11.2***	***x***	***x***	***60***	***66.67***
Shoulder	x	x	x	x	x	x	x	x	x	x	33.33
Arm/elbow	x	x	x	x	x	x	x	x	x	10	16.67
Hand/wrist/fingers	22.2	x	19.1	13.3	8.6	x	11.2	x	x	50	16.67
Lower Extremity	***44.4***	***80***	***33.3***	***66.7***	***40***	***100***	***37.3***	***x***	***x***	***20***	***33.33***
Leg	11.1	20	9.5	6.7	5.7	20	x	x	x	0	16.67
Knee	11.1	15	4.8	13.3	x	x	13.6	x	x	10	16.67
Ankle	x	x	9.5	6.7	14.3	20	x	x	x	x	x
Foot/toes	18.5	40	9.5	40	11.4	60	23.7	x	x	10	x
Other	*x*	*x*	*x*	*x*	*x*	*x*	*x*	*43*	*100*	*x*	*x*

KEY: x = no data

which is slightly higher than what was experienced in this study. Females sustained 33.33 percent of their injuries to their lower extremities, with the range for the published studies being 66.7 to 100 percent, which is much higher than the percentage in this study. This could be due in part due to the fact that the taekwondo competitors in this study are primarily recreational, therefore technique and competitiveness are inferior to those of elite levels, allowing for different trends injury distribution.

In the lower extremity, the knee and the foot/toes were the most commonly injured body parts, both in this study and two published studies (Zemper & Pieter, 1989; Beis et al., 2001). The foot is the main body part that connects when attacking with a kick, so injury to the foot and toes is very common in taekwondo. Due to the emphasis on swing kick in taekwondo, and the high torques on the knee during rotation, the knee is also a commonly injured body part in the lower extremity. In the upper extremity, the hand, wrist and fingers were the most commonly injured body parts across all studies, including this one. Taekwondo also incorporates punches and blocking techniques utilizing the hand and wrist, perhaps increasing the risk for injury. Also, board and brick breaks are common in taekwondo, with the hand, wrist, and fingers incurring most of the blunt force.

Injuries to the upper and lower extremities occur in taekwondo due to the emphasis on kicking techniques to the major scoring regions of the upper extremity. Blocking is very important, with the upper extremities taking the majority of the forces from their opponent. Upper extremity striking techniques are commonly used in attacking an opponent, or to break bricks/boards. It would be expected to see a majority of the

injuries occur to the upper and lower extremities because of the nature of the sport with regards to striking and blocking.

The results of other studies are consistent, however, on the least commonly injured body regions with the spine/trunk, ranging from 11.1 to 17.1 percent of all injuries in the males, and one study reporting 6.7 of injuries to the trunk or spine in females. This study reported 10 percent of injuries affecting the spine or trunk in males, while the females did not incur any injuries to this body region. The head was a commonly injured body region in a few studies (Zemper & Pieter, 1989; Beis et al., 2001; Kazemi & Pieter, 2004). The proportion of head injuries ranged from 22.2 to 34.3 percent in males and 13.3 to 20 percent in females in other studies (see Table 23). In this study, males sustained 10 percent of injuries to the head. The females in the present study did not experience any head injuries.

The head in taekwondo is a major scoring region, so for the published studies to report the head as the third most commonly injured body region is not unexpected. However, the finding in the present study was that only 10% of injuries involved the head perhaps due to low amounts of competitive sparring, encouragement to avoid the region during sparring, and the wearing of head protection during sparring.

Injury Type

Table 24 shows a percent comparison of injury type for adult males and females. The most common injury type for males across the published studies was contusion, ranging from 14.3 to 57 percent of total injuries. In this study, the most commonly occurring injuries for males were contusion and laceration, both incurring 30 percent of

total injuries. Contusion was also the most frequent injury in females in the published studies, ranging from 46.7 to 100 percent, but in this study the women only sustained contusions in 16.67 percent of their injuries, possibly due to the fact that competitive sparring was infrequent and training was more focused on taekwondo techniques. Instead, this study reported females sustaining 50 percent of their injuries due to joint dysfunction (subluxation, cartilage damage). Taekwondo is a high-contact sport, especially during sparring, so contusion is likely to occur due to the impact from striking maneuver.

In the published research (Table 24), ligament sprains (3.7 – 28.6%) and muscle strains (3.7 – 11.4%) are the second most common injury types reported for males in taekwondo, followed closely by fractures. This study reported dislocations as the second most common injury (20%) in adult males, with dislocations primarily involving the fingers. Muscle strains accounted for 10 percent of injuries in males, particularly to the low back, as a result of falling. Sprains and strains were the second most common injury occurring in females, along with contusion, at 16.67 percent each. Strains in females were a result of continual stepping back from attacks and stretching the muscles of the lower leg as they were eccentrically contracting. Ligament sprains in females primarily affected the knee and may relate to the rotational forces at the knee that occur during taekwondo.

Metacarpal fractures and dislocations are common in taekwondo due to the frequent use of open hands instead of closed fists (Pieter & Zemper, 1997). There were no fractures reported in this study, but they range from 7.84 to 14.8 percent in published studies. Joint dysfunctions in this study occurred to the shoulder (subluxation) and elbow

Table 24. A percent comparison of injury type for males and females in adult taekwondo.

Study	Sex	# inj	Contusion	Spr.	Str.	Fx	Conc.	Jt Dys	Lacer.	Disloc.	Epistaxis	Other
Zemper & Pieter, 1989	M	27	63	3.7	3.7	14.8	3.7	x	3.7	x	x	3.7
	F	20	75	5	5	x	5	x	x	5	x	5
Beis et al., 2001	M	21	52.4	4.8	x	14.3	4.8	x	14.3	4.8	4.8	x
	F	15	46.7	x	x	x	x	x	6.7	6.7	6.7	x
Kazemi & Pieter, 2004	M	35	14.3	28.6	11.4	x	8.6	x	14.3	x	2.9	17.1
	F	5	60	20	20	x	x	x	x	x	x	x
Zetou et al., 2006	M/F	360	41.4	30.5	x	11.2	x	x	41.4	x	3.4	13.5
Beis et al., 2007	M	7	57	x	x	x	14.3	x	14.3	x	14.3	x
	F	1	100	x	x	x	x	x	x	x	x	x
Kazemi et al., 2009	M/F	891	36.25	18.86	14.66	7.84	5.91	7.27	2.05	1.25	1.25	4.66
THIS STUDY 2013	M	10	30	x	10	x	x	x	30	20	10	x
	F	6	16.67	16.67	16.67	x	x	50	x	x	x	x

KEY: x = no data

(hyperextension) in females. One participant had a history of shoulder problems, particularly with the labrum, which compromises the stability of the shoulder joint. When the labrum is compromised, and the shoulder is continually exposed to forceful stimuli, the humeral head is typically forced out of (or to the rim of) the glenoid of the scapula. The hyperextended elbow in this study occurred while blocking, forcing the locked elbow into hyperextension.

The lacerations that occurred in this study (30%) were primarily from the fingernails and toenails of other competitors contacting their skin and cutting them, however some lacerations occurred from striking bricks and boards. Lacerations typically range from 3.7 to 14.3 percent in males, and only one study reported lacerations in females, accounting for 6.7% of injuries (Beis et al., 2001). There was an episode of epistaxis in this study, with no mechanism of injury, and epistaxis typically ranges from 1.5 to 14.3 percent in other studies.

Injury Onset

The majority of injuries in taekwondo are acute or sudden onset in nature (Pieter et al., 2005). According to Pieter (2005), little information is available on such factors as frequency or duration of training as they relate to taekwondo injury. This study attempted to determine the frequency and duration of training sessions. During this study, training occurred twice each week for each of the training groups, one hour per training session, lasting almost three months in length. Due likely to the relatively low frequency of training regimens for participants in this study and the shorter length of the taekwondo season, overuse/chronic injuries were not apparent. Chronic injuries will usually appear after multiple weeks of aggressive training and competitions, with little rest in between.

Children typically have lower rates of gradual onset injuries compared to adults. For example, Pieter and Zemper (1997) reported that 1.4% and 3.5% of all injuries in youth, male and female participants, respectively, were of a chronic onset. This study reported no chronic injuries in the youth, which may also reflect the small sample size of this group. Zetou et al. (2006) studied adult taekwondo injuries at the Greek taekwondo National division championships and found 30% of injuries were of chronic onset while the other 70% were of acute or sudden onset, which is most common in taekwondo. Pieter and Zemper (1989) reported a gradual onset injury rate of 0.45 injuries per 1,000 AEs, while this study reported chronic injuries with a rate of 0 per 1,000 AEs.

Timing of Injury

Most of the injuries in the present study were sustained during training (68.75%) while 31.25% of all injuries were sustained during competition. During training in this study, 31.25% percent of all injuries occurred in the first half of practice, while 37.5% of injuries occurred in the second half of practice. No data have been reported on training injuries in the studies reviewed; however, in the second half of training, participants may have been fatigued and neglected to execute proper techniques.

All of the competition injuries sustained in this study occurred in the second half of the competition. There were a total of 5 competition injuries (3 males and 2 females), In contrast, Beis et al. (2001) reported that males and females sustained most of their injuries in the first half of competition. Caine et al. (2006) reported that there is a relationship between time into competition and an increased frequency of injury in many sports.

Mechanism of Injury

Table 25. Mechanism of Injury in Males and Females in Adult Taekwondo.

	Zemper & Pieter, 1989		Beis et al., 2007		Kazemi et al., 2009	Beis et al., 2001		Zetou et al., 2006	Kazemi & Pieter, 2004		THIS STUDY 2013	
	Male	**Female**	**Male**	**Female**	**Male/Female**	**Male**	**Female**	**Male/Female**	**Male**	**Female**	**Male**	**Female**
n =	27	20	7	1	891	21	15	360	35	5	10	6
	per 100 A-E		per 1,000 A-E		% of injuries	% of injuries		% of injuries	per 1,000 A-E		% of injuries	
Unblocked attack	5.19	1.32	5.87	x	1.8	x	x	x	x	x	x	x
Attacking kick	2.36	3.6	x	x	34.7	71.4	33.4	x	x	x	x	x
Blocking a kick	2.83	1.35	x	x	43.9	x	x	x	x	x	x	x
Attacking punch	1.42	0	x	x	1.2	x	x	x	x	x	x	x
Blocking a punch	0.47	0	x	x	2.6	x	x	x	x	x	x	x
Receiving a blow	8.02	3.15	x	x	x	x	x	35.6	27.4	5.1	30	33.33
Delivering a blow	3.78	3.15	x	x	x	x	x	x	16	10.1	x	x
Fall	0.47	x	x	x	3.9	x	x	x	x	x	10	x
Impact w/ Surface	x	x	x	x	x	x	x	x	x	x	30	33.33
Other/unspecified	0.94	3.15	0.98	2.43	x	28.6	66.6	64.4	36.6	10.1	30	33.33

KEY: x = no data

This study reported only a few mechanisms of injury that were similar to published studies. Table 25 shows a both a percent and rate comparison of mechanism of injury in adult males and females. For adult males, the most common mechanism for injury was receiving a blow, ranging from 8.02 to 27.4 injuries per 1,000AEs. For adult females, the most common mechanism of injury is attacking with a kick, accounting for 33.4 percent of all injuries in one study (Beis et al., 2004). In this study, the two most common mechanisms for males were receiving a blow and impact with a surface (30% for each). Ten percent of the injuries in the males occurred as the result of a fall, which was the third most common mechanism. In the present study, the two most common mechanisms of injury for females were also receiving a blow and impact with a surface (33.33% for each). The females also had 33.33 percent of their injuries by other mechanisms not common with other studies, possibly a result of inexperienced competitors and the recreational nature of the taekwondo in this study.

A high percentage of injuries in other studies were "other/unspecified", ranging from 28.6 to 66.6 percent, indicating that there is a wide range of injury mechanisms in taekwondo. In this study, "other" mechanisms included finger and hand injuries from a "pulling" on the hand or fingers by the opponent during self-defense drills, self-defense holds, and board/brick breaks. Board and brick breaks were the most common "other" injury mechanism. It is surprising that in this study, there were no injuries related to attacking with a kick or receiving a blow. With the amount of sparring in taekwondo, and the wide range of experience in this study, it would be expected to see more injuries as a result of attacking and more injuries as a result of receiving an unblocked attack.

Time Loss

Taekwondo is reported to have more time-loss injuries than other martial arts because it is full-contact (Zetaruk et al., 2004). Time-loss was reported a bit differently for this study, although the terminology is still the same. Injury severity is defined as how serious an injury is and graded on an injury severity scale: Mild (no time loss to less than a week of time loss); moderate (time loss of one week to one month); severe (time loss more than one month). In this study, all injuries were considered mild injuries. Time-loss injury rates have been seen to vary for adult males from 6.85/1,000AEs to 33.56/1,000AEs, but in this study the time-loss injury rate for males was 0 injuries per 1,000 athletic-exposures.

For females, time-loss injury rates may range from 2.43 injuries to 23.03 injuries per 1,000AEs, as reported in the literature (Pieter & Zemper, 1997; Beis et al., 2007; Zemper & Pieter, 1998; Pieter, 2010). In this study, only one female incurred a time-loss injury, accounting for 6.25% of total injuries, and a rate of 2.18 time-loss injuries per 1,000 athletic-exposures. The female's time-loss injury rate of 2.18/1,000AEs is similar to that of Beis et al. (2007) who reported a time-loss injury rate of 2.43 per 1,000AEs. Adult males in previous studies did not sustain more time-loss injuries, but their time-loss injury rates were typically higher.

Risk Factor Analyses

The impact of risk factors – gender, age, height, weight, experience, rank, previous injury history (having a previous injury in taekwondo within the previous 12 months), specific injury history (injury history from the previous year regarding specific

injury, if re-injury occurs), having an unrelated injury during the season (if having an unrelated injury during the season increases risk for other unrelated injuries) and use of protective equipment – on incidence rate ratios were analyzed via Poisson regression. Each risk factor was initially modeled alone in an unadjusted Poisson regression. To incorporate correlations between the risk factors, adjusted incidence rate ratios (and associated 95% confidence intervals) were estimated from multiple Poisson regression.

Univariate Analyses

Analysis of gender, experience, and rank resulted in non-significant effect. In contrast, age, height, weight, and having an injury specific (injury of the same description) history were significantly associated with a reduction in the risk for injury per 1,000 AEs. Having a previous injury in taekwondo 12 months prior to the start of this study was shown to increase risk for injury during the study. Also, having an unrelated injury during the season was significantly associated with an increase in the risk of injury.

Age as a risk factor for injury has been extensively studied; however, research findings have been mixed. In this study, age was significantly associated with a reduction in risk for injury before adjusting for other factors. Some studies have shown an increase in injury rate with age (Beis et al., 2001; Zetaruk et al., 2004) while some research has shown a decrease in injury with age (Pieter, 2002).

Height as a risk factor for injury in taekwondo has not been previously studied, but in this study it was significantly associated with a reduction in the risk for injury. Prior to this study, weight as a risk factor for injury in taekwondo has not been tested for

significance. In this study, decreased weight was significantly associated with a reduction in the risk for injury. Height has not been tested alone in other studies, as height tends to increase with weight, so a better understanding of height and weight as risk factors for injury needs to standardized (i.e. BMI).

Having a previous injury in taekwondo in the previous twelve months was shown to be significantly associated with an increase in the risk for injury during this study. This study showed that if a competitor sustains an injury in taekwondo, their chances of sustaining another injury in taekwondo within twelve months are increased. Birrer (1996) suggests that injury rates are higher if there is a history of injury. Also, Kazemi et al. (2009) found that 11.86% of injuries are attributed to previous injury ($p=0.008$).

During this study, having a specific injury history in taekwondo was shown to be significantly associated with a reduction in the risk for injury. Although follow-up on re-injury in taekwondo is scarce, Zetou et al. (2006) reported that 40% of injuries in females and 60% of injuries in males are a result of a previous injury.

Having an unrelated injury during the season was another risk factor that has not been previously studied in taekwondo research. If a participant had an unrelated injury during the season, they were at an increased risk for incurring another unrelated injury, and this finding was significant. Once a participant sustains an injury, it is hypothesized that they compensate movements to avoid injuring the area, so injury may occur to another unrelated location on the body.

Multivariate Analyses

Due to the small number of participants and the relatively large number of variables in this study, only four factors were run using a multivariate analysis: gender, weight, previous injury history, and unrelated injury during the season. Only weight and unrelated injury during season were significant.

Weighing less in taekwondo was shown to be associated with a decrease in the risk for injury, possibly due to the younger, less experienced participants being injured less. Participants who carried more weight were typically older participants who had more years of experience in taekwondo. Pieter and Zemper (1997) hypothesized that increased body weight would increase risk for injury, since competitors are thought to get stronger and have more powerful attacks. This study showed that an increase in weight was associated with increased injury incidence in the study population.

Having an unrelated injury during the season was associated with having an increased risk for another injury, showing that participants, who were injured during the study, were more likely to have an unrelated injury during the study. No previous studies have looked at whether having an unrelated injury during observation increases risk for further unrelated injury. This finding is quite unique, in that perhaps once an injury occurs the participant becomes hesitant to expose the injury further, resulting in compromised movements, exposing non-injured body parts.

Study Limitations

Potential methodological weaknesses in this study included participant dropout, dishonesty on the Demographic and Previous Injury History form, errors on the injury reporting forms (both previous injury history and current injury). Also, due to the

frequency of training sessions over the course of the 12-week month observational period, the researcher was unable to be present for all training sessions or competitions, but visitations were made at least once every second week to follow-up with the athletes. The small sample size in this study also limited generalizability as well as the ability to run multivariate analyses on all of the possible risk factors.

Suggestions for Further Research

The strengths of this study are, as follows:

- It was the first study to report injury rates based on both exposure hours and athletic-exposures.
- It was one of the few studies to report both competition and training injury rates.
- One of the few studies to separate adult and youth injury rates during competition and training.
- The first study to show a relationship between the potential risk factors weight and unrelated injury and increased risk of injury.

Recommendations for future research include the following:

- Injury surveillance on larger populations of children participating in taekwondo competitions and training, comparing them with their adult counterparts.
- Additional prospective studies that follow taekwondo athletes for a longer period of time and determine the incidence of re-injury.

- Since very little is known about risk factors, more research should be done on selected risk factors and how they can affect injury rates in the young and adult taekwondo competitor. For example, weight as a risk factor needs to be more closely studied and tested for significance in order to determine a more consistent relationship between weight and injury in taekwondo.
- Future research should also include studying the effect of protective equipment on the incidence risk of injury.
- Height and weight should be tested together, with a number (i.e., BMI) that standardizes overall body size.

Conclusion

Taekwondo has become an increasingly popular sport in recent years, with more and more participants each year. With the explosion of participation in this sport, injury research has received more attention. This study calculated an injury rate for adult males of 68.49 injuries per 1,000 athletic-exposure and 1,000 hours of exposure and an injury rate for adult females of 35.50 injuries per 1,000 athletic-exposure and 1,000 hours of exposures. These numbers are typically higher than what has been reported elsewhere in published studies. No children or youth were injured in this study, so according to this research, taekwondo is a relatively safe activity for youth taekwondo competitors. Nonetheless, the number of children was limited to 7 so these results may not be representative.

Competition injury rates were higher than training injury rates, which was expected. Furthermore, the wrist, hand, and fingers were the most problematic areas for

participants in this study. This study found that contusions and lacerations were the most common injuries, which is similar to what has been reported in most previous taekwondo research. Of the risk factors that were examined in this study, age, height, weight, previous injury history, specific injury history, and having an unrelated injury during the season were all significantly associated with a reduction in risk of injury in univariate analyses, i.e., before adjusting for other factors. However, after adjusting for other factors using a multiple-Poisson regression, only weight and having an unrelated injury during the season were significant risk factors for injury.

This study contributed to the current literature by providing prospective data collection, injury rates in hours and athletic-exposures, and some preliminary findings on selected injury risk factors. Also, this study provided injury rate data during competition and training while following a taekwondo club forward in time. However, further, more long-term research is needed to better examine the incidence and distribution of taekwondo injuries in both the child and adult and to identify risk factors which may be modified as a basis for preventing injuries.

APPENDICES

Appendix A

Taekwondo Injury Reporting Form

Name _____

01. Sex (circle one): (1) Male (2) Female
02. Age: _____ years
03. Height: _____ in
04. Weight: _____lbs
05. Date of injury: _____
06. Weight division: Belt Color: _____
    (1) Fly Rank:
    (2) Feather (1) Low (0-1.5 yrs. Exp)
    (3) Light (2) High (1.5+ yrs. Exp)
    (4) Heavy
07. Injury occurred in:
    (1) Competition Bout #_____ Won Lost
    (2) Tournament
    (3) Training
08. Time of injury:
    Game: Practice:
    (01) 1st Round (06) First 1/2 hour
    (02) 2nd Round (07) Second 1/2 hour
    (03) 3rd Round (08) Third 1/2 hour
    (04) Overtime (09) Fourth 1/2 hour
    (05) Warm-up (10) Fifth 1/2 hr or more
09. This injury is a:
    (1) New injury
    (2) Recurrence of TKD injury from this season
    (3) Recurrence of TKD injury from previous season
    (4) Complication of previous TKD injury
    (5) Recurrence of other sport injury
    (6) Recurrence of non-sport injury
    (7) Complication of previous non-TKD injury
10. Has athlete had unrelated injury reported this season? (1) No (2) Yes
11. How long did this injury keep the athlete from unrestricted participation in TKD? (circle one):
    (0) Continued this day
    (1) 1 - 2 days
    (2) 3 - 4 days
    (3) 5 - 6 days
    (4) 7 - 9 days
    (5) 10+ days Exact # of days: _____
    (6) Catastrophic, non-fatal
    (7) Fatal
    (8) Observed for head injury, returned to activity
12. Did this injury result in the athlete discontinuing participation/competition during this day/match?
    (1) No (2) Yes (3) Yes-KO (4) Yes-TKO
13. Surface: (1) Mat (2) Hard surface
14. Injury situation (circle one):
    (01) Conditioning
    (02) Drills (with or without partner?)
    (03) Blocking a kick
    (04) Blocking a punch
    (05) Attacking - kick
    (06) Attacking - punch
    (07) Fall
    (08) Unblocked attack
    (09) Other_____
15. Injury mechanism (circle one):
    (1) Delivering blow
    (2) Receiving blow
    (3) Impact with surface
    (4) Sprints/running
    (5) No evidence of contact
    (6) Overuse/gradual onset
    (7) Lifting weights
    (8) Simultaneous blows
    (9) Other: _____

16. Primary type of injury (circle one):

(01) Abrasion
(02) Blister
(03) Burn
(04) Bursitis
(05) Cartilage-torn
(06) Concussion
(07) Contusion
(08) Dislocation
(09) Fracture
(10) Heat exhaustion
(11) Heat stroke
(12) Hemorrhage
(13) Hernia
(14) Hyperextension
(15) Infection
(16) Inflammation
(17) Internal injury
(18) Laceration
(19) Ligament(s)-complete tear
(20) Nerve injury
(21) Puncture wound
(22) Sprain
(23) Strain
(24) Rupture
(25) Stress fracture
(26) Subluxation
(27) Sub-periostal hematoma
(28) Tendon-torn
(29) Tendinitis
(30)Other:_____

17. Principal body part injured (circle one):

(01) Head (see #20/21)
(02) Eye(s)
(03) Ear(s)
(04) Nose
(05) Face
(06) Chin
(07) Jaw (TMJ)
(08) Mouth (see #20)
(09) Teeth
(10) Tongue
(11) Neck
(12) Breasts
(13) Shoulder
(14) Clavicle
(15) Scapula
(16) Upper arm
(17) Elbow
(18) Forearm
(19) Wrist
(20) Hand
(21) Thumb
(22) Finger(s)
(23) Upper back
(24) Spine
(25) Lower back
(26) Ribs
(27) Sternum
(28) Stomach
(29) Kidney
(30) Spleen
(31) Internal organs
(32) Gynecological organs
(33) Pelvis, hips
(34) Buttocks
(35) Groin
(36) Coccyx
(37) Testicles
(38) Upper leg
(39) Hamstrings
(40) Knee (see #22)
(41) Patella
(42) Lower leg
(43) Ankle
(44) Heel/Achilles
(45) Foot
(46) Toe(s)
(47) Other_____

HEAD INJURY INFORMATION (complete only if injury involved head or mouth)

18. Mouthguard worn?
    (1) MG worn - dentist-fitted
    (2) MG worn - self-fitted
    (3) MG not worn
19. This athlete was diagnosed as having:
    (0) Grade 0 cerebral concussion (Nelson)
    (1) Grade 1 cerebral concussion (AAN)
    (2) Grade 2 cerebral concussion (AAN)
    (3) Grade 3 cerebral concussion (AAN)
    (4) No cerebral concussion
    (5) Unknown

KNEE INJURY INFORMATION (complete only if this injury involved the knee) (circle all that apply)

20. Injury (circle all that apply):
    (1) Medial collateral ligament (MCL)
    (2) Lateral collateral ligament (LCL)
    (3) Anterior cruciate ligament (ACL)
    (4) Meniscus
    (5) Other: _____

21. Protection Worn:
    (1) Head gear
    (2) Torso protection
    (3) Hand protection
    (4) Elbow guards
    (5) Knee pads
    (6) Shin guards
    (7) Foot protection
    (8) Mouth guard

Appendix B

Demographic Information and Previous Injury History Form

Name: _____

Sex (Circle one): Male/Female

Birth date: _____ Age (years):_____

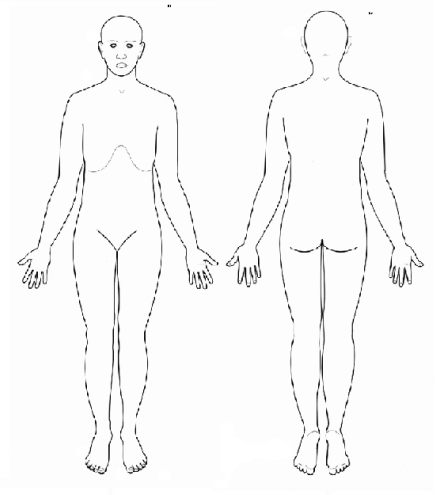
Years of taekwondo experience: _____ Belt Color: _____

Rank: _____

Height (inches):_____ Weight (lbs):_____

1. Have you had an injury/injuries while participating in taekwondo ONLY within the LAST 12 MONTHS? If so, how many?

2. If YES to the ABOVE question, please respond to the following questions and circle the information which applies to any/all injuries:
   a. Location of the injury (where on the body) (Locate all that apply for all injuries):



b. What was/were the injury/injuries?

(01) Abrasion
(02) Blister
(03) Burn
(04) Bursitis
(05) Cartilage-torn
(06) Concussion
(07) Contusion
(08) Dislocation
(09) Fracture
(10) Heat exhaustion
(11) Heat stroke
(12) Hemorrhage
(13) Hernia
(14) Hyperextension
(15) Infection
(16) Inflammation
(17) Internal injury
(18) Laceration
(19) Ligament(s)-complete tear
(20) Nerve injury
(21) Puncture wound
(22) Sprain
(23) Strain
(24) Rupture
(25) Stress fracture
(26) Subluxation
(27) Sub-periostal hematoma
(28) Tendon-torn
(29) Tendinitis
(30)Other:_____

c. How much time was lost from taekwondo activity for each injury, if any?

(0) Continued this day
(1) 1 - 2 days
(2) 3 - 4 days
(3) 5 - 6 days
(4) 7 - 9 days
(5) 10+ days Exact # of days: _____
(6) Catastrophic, non-fatal
(7) Fatal
(8) Observed for head injury, returned to activity

d. How did the injury/injuries happen?

(01) Conditioning
(02) Drills (with or without partner?)
(03) Blocking a kick
(04) Blocking a punch
(05) Attacking – kick
(06) Attacking – punch
(07) Fall
(08) Unblocked attack
(09) Other_____

e. What was the mechanism of injury(ies)?

(1) Delivering blow
(2) Receiving blow
(3) Impact with surface
(4) Sprints/running
(5) No evidence of contact
(6) Overuse/gradual onset
(7) Lifting weights
(8) Simultaneous blows
(9) Other: _____

f. Did the injury/injuries happen during a competition (one bout of 3 rounds), tournament, or training/practice?

(1) Competitin (bout of 3 rounds)
(2) Tournament
(3) Training/Practice

g. Did you get a medical diagnosis (from a doctor or other health care professional)? If YES, what was the diagnosis?

h. Was this a new injury/injuries?

(1) New injury
(2) Recurrence of TKD injury from the last 12 months ONLY
(3) Complication of previous TKD injury
(4) Recurrence of other sport injury
(5) Recurrence of non-sport injury
(6) Complication of previous non-TKD injury

i. Were you wearing protective equipment when this injury/injuries occurred? If so, what?

(1) head gear
(2) torso protection
(3) hand protection
(4) elbow guards
(5) knee pads
(6) shin guards
(7) foot protection
(8) mouth guard

3. Have you ever suffered a concussion or concussions (that was confirmed by a medical professional) while participating in taekwondo? If so, how many?_____

    a. Did a medical profession grade the concussion? If so, what grades were they?

    (0) Grade 0 cerebral concussion (Nelson)
    (1) Grade 1 cerebral concussion (AAN)
    (2) Grade 2 cerebral concussion (AAN)
    (3) Grade 3 cerebral concussion (AAN)
    (4) No cerebral concussion
    (5) Unknown

    b. Mouth guard worn?

    (1) MG worn - dentist-fitted
    (2) MG worn - self-fitted
    (3) MG not worn

    c. How long did each concussion keep you out of taekwondo?

Appendix C
Informed Consent

Title: The Epidemiology of Taekwondo Injury in Adults and Youth Competitors

Principle Investigator (PI): Matthew Carlson, Graduate Student, Department of Physical Education, Exercise Science, & Wellness, University of North Dakota, (813) 503-4071, matthew.f.carlson@my.und.edu. Student's Advisor, Dr. Dennis Caine, Interim Dean, College of Education and Human Development, University of North Dakota, (701) 777-2674.

Invitation to Participate: You are invited to participate in a research study on injuries affecting the taekwondo competitors at *Championship Taekwondo* in Grand Forks, North Dakota during the current enrollment period; March 4th (or a date soon after IRB approval is granted) through May 16th, 2013.

Statement of Research: A person who is to participate in the research must give his or her informed consent to such participation. A participant under 18 years of age must also have his/her legal guardians consent. This consent must be based on an understanding of the nature and risks of the research. This document provides information that is important for this understanding. Research projects include only subjects who choose to take part. Please take your time in making your decision as to whether or not you choose to participate. If you have questions at any time, please ask.

Purpose of Research: The purpose of this research study is to determine the incidence and distribution of injuries that affect adult and youth (7-17 years) taekwondo competitors throughout the course of training and competition during the spring 2013 session and to determine the relationship between injuries and potential risk factors including gender, previous years of taekwondo experience, previous injuries, and belt color. This research is important because to date there has been little injury research conducted that involves children and adolescent participants, and then compared to their adult counterparts (i.e., incidence and distribution of injuries).

Length of the Study: Your (or your child's) participation in the study will last as long as you (or your child) are enrolled at Championship Taekwondo during the spring 2013 session. You (or your child) will be contacted by the researcher at least once every two weeks to fill out an injury reporting form, if needed and to discuss in private any pain or injuries that you (or your child) have experienced during the previous week. An injury will be defined as "any body part (as a result of training or competition in taekwondo) that interferes with training or competition and is recorded on the first day of onset and every day thereafter until it does not interfere with training or competition." Depending on the extent of the pain and/or injuries, the injury report may take anywhere from 15 to 20 minutes to complete. The study will end at the end of your (or your child's) enrollment in the spring session at Championship Taekwondo.

What Will Happen During This Study: The first part of this study involves the completion of a questionnaire that asks about injuries that you (or your child) may have sustained during the past 12 months as a result of training or competition in taekwondo. Also on this form you will be requested to provide demographic information including age, sex, height, weight, rank, belt color, and years of experience in taekwondo. This questionnaire will take between 15-20 minutes to complete

The second part of this study will involve injury surveillance. All taekwondo injuries sustained during the surveillance period will be recorded. You (or your child) will be contacted in person at least once every two weeks to discuss any new or persistent injuries that you (or your child) may have experienced. If an injury has occurred you (or your child) will be asked to fill out an injury report form that asks several questions about the details of any pain or injury that you (or your child) are currently experiencing. Please notify the PI (Matthew Carlson) if you (or your child) have incurred an injury since his (the PI's) last visit.

Risks of the Study: This study is observational in nature and is intended to record any pain or injuries that occur during your (or your child's) taekwondo enrollment. There are no foreseeable risks to the participants. If any trauma occurs as a result of a participant's participation in taekwondo, he/she will be advised to seek proper medical care from a healthcare profressionals and can opt to drop out of this research study. Because the participants are asked to sign consent forms stating I (Matthew Carlson) nor the taekwondo academy are liable for any adverse reactions or injury, the participants are responsible for finding the proper medical treatment if any adverse reactions (e.g., trauma) occur.

Benefits of the study? You (or your child) may not benefit personally from being in this study. However, we hope that, in the future, others might benefit from this study because it will give both instructors and taekwondo competitors in-depth data on the incidence and distribution of injury and risk factors that may increase risk of injury. This information, in turn, may be used to identify injury prevention measures that may be tested to determine their effectiveness.

Confidentiality: All your (or your child's) data and information obtained through forms will remain confidential. Your (or your child's) identity will be withheld from all data files, sheets, and analyses through the use of a numeric coding system. In addition, you (or your child) will not be identified in any reports about this study that might be presented or published. All data will be retained for a period of 3 years following completion of this study in a locked container in the Physical Education, Exercise Science, and Wellness office. Any information that is obtained in connection with this study and can be identified with you (or your child) will remain confidential and will be disclosed only with your written permission.

Voluntary Participation: Your decision whether or not to participate is completely voluntary and no penalties will result from refusal to participate. Your decision whether or not to participate will not affect your (or your child's) current or future relations with the University of North Dakota or Championship Taekwondo. If you decide to participate, you are free to discontinue participation at any time. To discontinue participation, tell the researcher that you do not wish to continue with this project.

Contacts and Questions? The researcher conducting this study is Matthew Carlson, a UND graduate student in the Physical Education, Exercise Science, and Wellness department. You may ask any questions you have now. If you later have questions, concerns, or complaints about the research please contact Matthew Carlson at (813) 503-4071. You may also contact my thesis advisor, Dr. Dennis Caine, at (701)777-2674.

If you have any questions regarding your rights as a research participant, or if you have any concerns or complaints about the research, you may contact the University of North Dakota Institutional Review Board at (701) 777-4279. Please call this number if you cannot reach research staff, or you wish to talk with someone else.

Agreement: Your signature indicates that this research study has been explained to you, that your questions have been answered, and that you agree to take part in this study. You will receive a copy of this form.

Participant's Name:_____

Legal Guardian's Name:_____

_____

Signature of Participant Date

_____

Signature of Legal Guardian Date

Appendix D
The Epidemiology of Injuries in Adult and Youth Taekwondo Competitors
Assent Form for Minors (<18 years of age)

My name is Matthew Carlson. I am trying to learn about taekwondo injuries to learn how and why injuries happen in taekwondo. If you would like, you can be in my study.

If you decide you would like to be in my study, you will need to give me permission to allow me to record your injuries, if they happen. You will also be asked to fill out a form explaining any other injuries you have had in taekwondo. Also, I will meet with you at least once every second week to talk to you, to see if you have been hurt since the last time I saw you. If you have been hurt, I will need your help to fill out a form that tells me about your injury so I can understand more about the injury. Such meetings will not take longer than 10-15 minutes.

Even though I am exploring injuries in taekwondo, you will not be any more likely to get an injury than you would be if I was not doing this research. Because taekwondo involves kicking and punching, there is risk injury. Also, with your help in this study, children and youth in the future will be able to learn about injuries in taekwondo. So you are not only helping me, but you are also helping the sport of taekwondo.

Other people will not know if you are in my study. When I tell other people about my research, I will not use your name, so no one can tell who I am talking about.

Your parents or legal guardian have to say it's OK for you to be in the study. After they decide, you get to choose if you want to do it too. If you don't want to be in the study, no one will be mad at you. If you want to be in the study now and change your mind later, that's OK too. You can stop at any time.

My telephone number is (813) 503-4071. You can call me if you have questions about the study or if you decide you don't want to be in the study any more.

I will give you a copy of this form in case you want to ask questions later.

Agreement

I have decided to be in the study even though I know that I don't have to do it. Matthew Carlson has answered all my questions.

_____	_____
Signature of Study Participant	Date
_____	_____
Signature of Researcher	Date

Appendix E

HIPAA[1] AUTHORIZATION TO USE AND DISCLOSE INDIVIDUAL HEALTH INFORMATION FOR RESEARCH PURPOSES

1. Purpose. As a research participant, I authorize Matthew Carlson and Dr. Dennis Caine to use and disclose my (or my child's) (if the participant is less than 18 years of age) individual health information for the purpose of conducting the research project entitled: The Epidemiology of Taekwondo Injury in Adult and Youth Competitors.

2. Individual Health Information to be Used or Disclosed. The individual health information that may be used or disclosed to conduct this research includes: medical information arising from the research study that pertains to injuries that are sustained as a result of my (or my child's) participation in taekwondo and that restrict or hinder my (or my child's) ability to participate fully in taekwondo training or competition.

3. Parties Who May Disclose My Individual Health Information. The researcher and his advisor, Dr. Dennis Caine, may obtain my (or my child's) individual health information from the medical information provided on the previous injury history form, from injury records kept at Championship Taekwondo, directly from me, or from my legal guardian. The owners of Championship Taekwondo – Shane and Tina Hylton – will not be involved in the collection, storage, or analysis of data associated with this study.

4. Parties Who May Receive or Use My Individual Health Information. The individual health information disclosed by parties listed in item 3 and information disclosed by me (the participant, or the minor's parent/legal guardian) during the course of the research may be received and used by Matthew Carlson and his advisor, Dr. Dennis Caine. The owners of Championship Taekwondo – Shane and Tina Hylton – will not be involved in the collection, storage, or analysis of data.

5. Right to Refuse to Sign this Authorization. I (the participant, or minor's parent/legal guardian) do not have to sign this Authorization. If I (the participant, or minor's parent/legal guardian) decide not to sign the Authorization, I (the participant, or child being recruited) will not be allowed to participate in this study. However, my (the participant, or minor's parent/legal guardian) decision not to sign this authorization will not affect any other treatment, payment, or enrollment in health plans or eligibility for benefits.

[1] HIPAA is the Health Insurance Portability and Accountability Act of 1996, a federal law related to privacy of health information.

6. Right to Revoke. I (the participant, or minor's parent/legal guardian) can change my (the participant, or minor's parent/legal guardian) mind and withdraw this authorization at any time by sending a written notice to Matthew Carlson at matthew.f.carlson@my.und.edu or by calling the principle researcher, Matthew Carlson's cell phone at (813) 503-4071 to inform the researcher of my decision. If I (the participant, or minor's parent/legal guardian) withdraw this authorization, the researcher may only use and disclose the protected health information already collected for this research study. No further health information about me (the participant, or the minor involved) will be collected by or disclosed to the researcher for this study. Confidentiality will be respected as noted above.

7. Potential for Re-disclosure. My (the participant, or minor's <18 years of age) individual health information disclosed under this authorization may be subject to re-disclosure outside the research study and no longer protected. For example, researchers in other studies could use my (the participant, or minors <18 years of age) individual health information collected for this study without contacting me (the participant, or minor's parent/legal guardian) if they get approval from an Institutional Review Board (IRB) and agree to keep my (the participant or minor's) information confidential.

7A. Also, there are other laws that may require my (the participant or minor's) individual health information to be disclosed for public purposes. Examples include potential disclosures if required for mandated reporting of abuse or neglect, judicial proceedings, health oversight activities and public health measures.

This authorization does not have an expiration date.

I am the research participant or personal representative authorized to act on behalf of the participant.

I have read this information, and I will receive a copy of this authorization form after it is signed.

_____	_____
Signature of research participant or research participant's personal representative	Date
_____	_____
Printed name of research participant or research participant's behalf personal representative	Description of personal representative's authority to act on behalf of the research participant

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