UNIVERSITY OF ALBERTA

POSSIBLE CONCUSSIONS FOLLOWING A HEAD BLOW IN COMPETITION TAEKWONDO

by

Jae Ok Koh ©

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of Doctor of Philosophy

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DEDICATION

To my all family members and

To the past: Mom and Dad

In the memory of my parents

I wish you were here to see your daughter this day.

Maybe you are…

ABSTRACT

The purpose of this thesis is to study head blows and concussions in competition Taekwondo. To achieve this, I completed four studies.

In Study 1, I measured incidence and described characteristics of injuries sustained during the 1999 World Taekwondo Championships in Edmonton, Canada. The injury rate was 109/1,000 athlete-exposures. The concussion rate was 8/1,000 athlete-exposures.

In Study 2, I analyzed videotapes of the fighting conditions under which head blows commonly take place, to determine the conditions under which injury may occur. Head blows were associated with a direct head/face contact, a closed sparring stance, a shorter athlete, an axe/roundhouse kick, attacker's offensive kick, and a head blow recipient's absence of a blocking skill. The head-blow rate was 365/1,000 athlete-exposures.

In Study 3, I completed a systematic literature review of the incidence of concussion in contact sports. Ice hockey and rugby have the highest incidence of concussion and soccer has the lowest. Male boxers and female Taekwondo competitors have the highest frequency of concussion at the recreational level.

In Study 4, I examined the incidence of head blows and concussions, and examined some factors associated with them in young (11-19 year-old) Korean Taekwondo competitors. I used videotape analysis to examine contextual factors surrounding head blows, with a view of making recommendations reduce their frequency. The incidence of concussions and head blows was 50 and 226/1,000 athlete-exposures, respectively. A multinomial logistic model shows that head blows and concussions are associated with younger age and lack of blocking skills. Head blows and concussions occur more commonly when competitors adopt a closed or a clinched sparring stance, during an attacker's offensive single kick, when the defender lacks blocking skill, when the defender has a similar or shorter height than the attacker, and during single elimination matches. The most frequent site of impact is the temporal region of the head.

In conclusion, the incidence of head blows and concussions is high in competition Taekwondo. This could be decreased with improved by promoting skill to block kicks to the head.

Key Words: Head blow; Concussion; Brain Injury; Incidence; Competition Taekwondo

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CHAPTER 1

INTRODUCTION

Martial arts are participated in for several purposes, including self-defense, sport, physical and mental conditioning, and spiritual reasons (Finkenberg, 1990). Taekwondo is a Korean martial art with origins dating back at least 1,000 years (Feehan & Waller, 1995). In its modern form, it is an increasingly popular sport worldwide since 1950. Taekwondo is practiced in at least 140 countries, and 120 nations are official members of the sport's major organizing body, the World Taekwondo Federation (WTF). The WTF was admitted to the Olympics in 1988, and Taekwondo was a demonstration sport in the 1988, 1992, and 1996 Olympic games (Feehan & Waller, 1995). Furthermore, competition Taekwondo[1] became an official event in the 2000 Olympics in Sydney, Australia. Taekwondo is highly focused on both physical and mental discipline.

Blows to the head region occur commonly in competition Taekwondo, since the face is a major scoring region. Several studies have reported the incidence of concussion in competition Taekwondo. These studies may underestimate the occurrence of concussion because the data have been acquired from the obvious by knocked-down or knocked-out athletes. This would exclude concussed athletes with no overtly apparent symptoms or signs. This same problem could exist in other contact or collision sports. In general, there has been a lack of concern over athletes who have sustained repeated head blows or mild concussions with no loss of consciousness or instantly apparent symptoms or signs. Yet such incidents may lead to short-term or even long-term health

[1] Competition Taekwondo refers to full contact sparring.

consequences for the competitors. Also, these considerations can have a significant impact on the continuance of an athletic career, causing temporary suspension of play and even early retirement in some cases. It is important to quantify the frequency of all direct head blow events and to investigate the head blow receiver's experiences at the time of head impact and post-impact. Such data will provide players, parents, coaches, and referees with a better understanding of the risks associated with participation in this sport. This may also lead to changes in the sport generally, through rules, coaching strategies, and practice traditions, that can improve the safety of Taekwondo. The general focus of this dissertation is to quantify the frequency of potential concussions and head blows, and to determine the contexts in which such blows are received. The ultimate goal of this research program is to improve the sport of Taekwondo such that its benefits outweigh its risks.

LITERATURE REVIEW

This narrative review of literature consists of two major sections. The first part will review the general information on concussion and sport-related concussion. The second part will focus on incidence of martial arts injuries and competition Taekwondo injuries. Finally, a summary will be provided of the research conducted to date on sport-related concussion and future research directions will be suggested.

1. Concussion

Before the 1980's, the medical profession did not fully recognize mild head injury (concussion) in sports as a significant problem due to a lack of research studies.

However, Symonds (1962) described the possible long-term implications of concussion, stating that "it is questionable whether the effects of concussion, however slight, are ever completely reversible." Some studies suggest that concussions can cause problems and multiple concussions might increase the probability of significant long-term behavioral or cognitive damages. However, these findings are controversial because other studies show a lack of serious sequelae after concussion (McCrory, Johnston, & Mohtadi, 2001; Rabadi & Jordan, 2001; Gaetz, Goodman, & Weinberg, 2000; Master, Kessels, Lezak, Troost, & Jordan, 2000; Wilberger, 1999; Parkinson, 1992; Sortland & Tysvaer, 1989; Hugenholtz, Stuss, Stethem, & Richard, 1988; Gerberich, Priest, Boen, Straub, & Maxwell, 1983; Gronwall & Wrightson, 1975).

Definitions of concussion

Usually the term concussion is used to describe a mild traumatic brain injury or a mild head injury. The definition of mild traumatic brain injury is traumatically induced physiological disruption of brain function, as manifested by at least one of the following: loss of consciousness less than 30 minutes; loss of memory less than 24 hours after or before the event; Glascow Coma Scale of 13-15; alteration in mental state (e.g., feeling dazed, disoriented, or confused); and focal neurological deficits that may or may not be transient (The Mild Traumatic Brain Injury Committee of the Head Injury Interdisciplinary Special Interest Group of the American Congress of Rehabilitation Medicine, 1993). There is no universal agreement on the definition of concussion at present. Concussion has been defined in various ways, but generally it means an alteration of cerebral function without changes in brain structure (Bailes, 1998). The concussion [Latin concussus, “a shaking,” from concutio, “I shake violently” (Skinner, 1961)] is a constellation of symptoms and signs such as memory problems, headache, dizziness, and/or other complaints that begin as an immediate consequence of a brain injury (Rizzo & Tranel, 1996). The Committee on Head Injury Nomenclature of the Congress of Neurological Surgeons (1966) has defined concussion as “a clinical syndrome characterized by immediate and transient post-traumatic impairment of neural function, such as alteration of consciousness, disturbance of vision, equilibrium, etc. due to brainstem involvement.” In addition, the American Academy of Neurology (1997) and Kelly et al. (1991) have defined concussion, especially for athletic purposes, as “a trauma-induced alteration in mental status that may or may not involve loss of consciousness.” Confusion and amnesia are the hallmarks of concussion. In 2001, the Concussion in Sport (CIS) Group developed a definition of concussion as “ a complex pathophysiological process affecting the brain, induced by traumatic biomechanical forces” (Concussion in Sport Group, 2002).

Mechanism and pathophysiology of concussion

The brain is protected by several layers, including the meninges, cerebrospinal fluid, a non-expandable bony vault, and a thick scalp. Despite this protection, biomechanical forces that are direct or indirect (e.g. whiplash) can cause brain injury.

The severity of brain injury is affected by the speed, site, and direction of impact (Binder, 1986). There are three mechanisms of dynamic forces that produce skull and brain injuries (Cantu, 1998b; 1997; 1992). First, a powerful blow to the resting head usually produces maximal brain injury beneath the site of cranial impact (known as a coup injury). Such a case generates acceleration forces that cause the brain to collide against the cranial vault. This occurs, for example, when the head is in a resting state, and is forcibly struck by another object, such as a hook in boxing, an opponent's football helmet in football (Albright, Mcauley, Martin, Crowley, & Foster, 1985), or a roundhouse kick or spinning kick in Taekwondo. Second, the brain accelerates away from the initial impact and collides with the opposite side of cranial vault (known as a contra-coup injury). In this situation, deceleration forces generate the contra-coup injury. Mostly, concussions are caused by acceleration or deceleration forces or both (Fick, 1995). Third, if a skull fracture is present, the first two principles may not apply, because the bone itself is either transiently (linear skull fracture) or permanently (depressed skull fracture) displaced at the moment of impact and may directly damage the brain tissue.

According to Elson and Ward (1994), head accelerations, either translational (acceleration along a line that can be any direction) or rotational acceleration (acceleration of the head about an axis passing through the head), are commonly accepted as the cause of mild brain injury. Also, they point out that almost any injury event involves a combination of the two accelerations (Bailes, 1998; Elson & Ward, 1994). For example, executing a roundhouse kick or spinning kick to the mandible generates rotational forces in Taekwondo, although there is no direct study available to support this assumption.

In an early study conducted by Ommaya and Gennarelli (1974) on the effects of different impacts on monkeys, they observed that all the animals in the rotated group showed neurological evidence of experimental cerebral concussion, defined as the sudden onset of paralytic coma or traumatic unconsciousness. On the other hand, none of the translated group showed this effect. In addition, shear strains generated by rotation should cause both cerebral concussion and contre-coup contusions (Holbourn, 1943). These shearing forces occur whenever rotational movement of the brain is hindered (Leblanc, 1999). There are three areas where shearing forces occur: the dissipation of the cerebrospinal fluid between the skull and brain, attachments between the dura mater and brain, and irregular bony surfaces such as opposite to the temporal and frontal lobes (Leblanc, 1999; Cantu, 1998b; Ommaya, 1995; Ommaya & Gennarelli, 1974). Once shearing forces are generated by rotational acceleration as a result of a forceful blow to the head, the entire brain is vulnerable to these forces. Due to this, a concussion could be considered a diffuse brain injury (Leblanc, 1999).

Several different researchers have reviewed physiochemical abnormalities and metabolic alterations following mild to severe head injuries. Physiochemical abnormalities associated with head injuries include both an increase in the demand for fuel (glucose) and a reduction in cerebral blood flow (fuel delivery) due to the loss of metabolic autoregulation, alterations in the blood brain barrier, increases in concentrations of acetylcholine, potassium, and excitatory amino acids in the cerebrospinal fluid, and changes in water and electrolyte distributions such as increasing calcium and decreasing magnesium. These changes and alterations may result in progressive secondary injury (e.g. brain swelling and ischemia, elevation in intercranial pressures) to viable brain tissue through several mechanisms. In addition, genetic factors also may play a role in head injuries. The apolipoprotein E4 allele appears to be associated with increased severity of chronic neurological deficits in boxers for example

(Giza & Hovda, 2001; Maroon et al., 2000; Kelly, 1999; Wojtys et al., 1999; Wrightson & Gronwall, 1999; Hayes & Dixon, 1994).

Signs and symptoms of concussion

The common signs of concussion are a brief (from seconds to minutes) loss of consciousness, altered levels of consciousness, dazed appearance or unsteady gait, blank facial appearance, amnesia, size difference in pupils, poor concentration ability, and apprehension (Leblanc, 1999; Wojtys et al., 1999; Sturmi, Smith, & Lombardo, 1998; the American Academy Neurology, 1997; Symonds, 1962). On closer inspection, concussed athletes show the following symptoms: slower responses to questions, difficulty following instructions, disjointed speech patterns, emotional alterations, and/or vacant stares. Other common symptoms of concussion are confusion, disorientation, headaches, vertigo, ringing in the ear, blurred vision, double vision, tunnel vision, fatigue, cognitive and memory dysfunction, nausea, vomiting, photophobia, or a balance disturbance (Leblanc, 1999; Wojtys et al., 1999; Sturmi, Smith, & Lombardo, 1998; Symonds, 1962).

Such symptoms are very common in concussed people. However, it is interesting that the same complaints are commonly reported by people who have not had head injuries. For example in one study, headaches, fatigue, light sensitivity, irritability, loss of temper, and anxiety were common in both head injured subjects and non-head injured subjects, while sensitivity to noise, insomnia, memory difficulties occurred more frequently in the head injured subjects at one month post injury (Dikmen, Mclean, & Temkin, 1986). In general, headaches, insomnia and memory problems are common in the general population and in athletes, unrelated to head injury.

Systems for grading concussion severity

Classifying the severity of concussion is important in evaluation, management (Nelson, Jane, & Gieck, 1984), and development of guidelines for return to play (Cantu, 1998b). There have been a number of proposed sets of guidelines for grading the severity of concussions. Cantu's, the American Academy Neurology (AAN), and the Colorado Medical Society guidelines are commonly used in sport events because these are handy for on the field evaluations. AAN, Cantu and the Colorado Medical Society guidelines are divided into three grades. The AAN and Colorado Medical Society guidelines are a little more conservative than that of Cantu because they consider that concussions with loss of consciousness are more severe than concussions without loss of consciousness (Kelly, 2001). There are several reasons for these issues. For example, Kelly, McCrea, and Randolph (2000) found that seven subjects with 'loss of consciousness' with concussion required more time to recover their cognitive functions than a group with 'no loss of consciousness'. Other research conducted by Szymanski and Linn (1992) showed that loss of consciousness has been correlated with diffuse axonal injury in the parasagittal regions, possibly owing to damage to neurotransmitter function. According to Plum and Posner (1982), any period of unconsciousness from trauma is due to brain dysfunction of the cerebral hemispheres or to damage reaching within the deep structures of the brain, including the reticular activating system, which regulates sleep and wake cycles (Gennarelli, 1986). Animal studies support the view that loss of consciousness is associated with the severity of the injury. For example, a greater degree of force (Denny-Brown & Russell, cited by Lovell, Iverson, Collins, McKeag, & Maroon, 1999), such as rotational acceleration (Ommaya & Gennarelli, 1974) and rapid lateral acceleration and deceleration (Gennarelli et al., cited by Lovell et al., 1999), is required to produce loss of consciousness. Such evidence implies that there are underlying neurophysiological and perhaps even structural abnormalities that occur in the brain after minor head injury, however this damage is usually not detected by neuroimaging (CT or MRI).

On the other hand, studies conducted by Iverson, Lovell, and Smith (2000) and Lovell et al. (1999) found no significant differences between groups of subjects with loss of consciousness, no loss of consciousness, or uncertain loss of consciousness for any of the neuropsychological measures they used. However, there are methodological problems in these two studies including the possible misclassification of the subject groups and variable time of performing neuropsychological test postinjury. Also, Leininger, Gramling, Farrell, Kreutzer, and Peck III (1990) found similar results on neuropsychological tests between concussed patients without loss of consciousness and concussed patients with loss of consciousness. Continued research is required to determine the relative importance of signs/symptoms of concussion in athletes.

Cantu classified the severity of concussion based primarily on loss of consciousness (LOC) and the length of posttraumatic amnesia (PTA). Yarnell and Lynch (1973) suggested that evaluation of memory is a crucial feature in the assessment of mild concussion. The Cantu system is divided into 3 grades. Grade 1 concussions (mild) are those with no LOC and less than 30 minutes of PTA. Grade 2 concussions (moderate) are those with an LOC less than 5 minutes or PTA between 30 and 24 hours. Grade 3 concussions (severe) are those with an LOC greater than 5 minutes and PTA greater than or equal to 24 hours.

On the other hand, the Colorado Medical Society' and AAN grading systems are based on LOC. In the Colorado Medical Society grading system Grade 1 concussions (mild) consist of those with confusion without amnesia and no LOC, while Grade 2 concussions (moderate) consist of those with confusion with amnesia and no LOC. Grade 3 concussions (severe) include any LOC of seconds to minutes. Cantu (1997) criticized this system in suggesting that profound memory impairment represents a more serious degree of brain insult than does a brief period of unconsciousness, and thus, memory loss should be more prominent a feature of grading systems for concussion.

In the AAN grading system Grade 1 concussions (mild) involve transient confusion, no LOC, and a resolution of concussion symptoms within 15 minutes, while Grade 2 concussions (moderate) consider transient confusion, no LOC, and concussion symptoms which persist longer than 15 minutes. Grade 3 concussions (severe) include any cases of LOC of seconds to minutes.

There are other proposed guidelines for grading systems of concussion such as Torg's (1991) and Nelson et al.'s (1984). These systems consist of more than 3 grades. For example, Nelson et al., divided concussions further into 5 grades: Grade 0 is head struck or moved rapidly, not stunned or dazed initially, and no subsequent symptoms. Grade 1 is stunned or dazed initially, no LOC or amnesia, Bell rung (a mild form of concussion or a grade 1 concussion), and sensorium clears in less than 1 minute. Grade 2 is no LOC, clouded of sensorium longer than 1 minute, amnesia, confusion, dizziness, and irritability. Grade 3 is LOC of less than 1 minute and Grade 2 symptoms, and Grade 4 is LOC of longer than 1 minute and Grade 2 symptoms.

Although all of these concussion-grading schemes are used, they have been criticized because of a lack of supporting scientific research or lack of evidence-based data for establishing validity (Bailes & Hudson, 2001; Johnston, McCrory, Mohtadi, & Meeuwisse, 2001; Terrell & Tucker, 1999; Leblanc, 1999; McCrory, 1999). More research is required to establish a valid association between concussion and concussion signs, such as LOC, amnesia, and confusion.

Return to sport following concussion

Concussion management guidelines have been constructed to establish general rules for return to play, even though there is limited scientific knowledge regarding the concussion recovery process in athletes. To examine deficits induced by the concussion, several studies have been conducted using neuropsychological tests or devices for balance testing after concussion (McCrea, 2001; Hinton-Bayre, Geffen, Geffen, McFarland, & Friis, 1999; Guskiewicz, Riemann, Perrin, & Nashber, 1997; Guskiewicz, Perrin, & Gansneder, 1996; Maddocks & Dicker, 1989). These studies suggested that the results of neuropsychological tests and balance tests could be useful to make decisions regarding return to sport. The purpose of the current guidelines for returning to play after concussion is to minimize or prevent the possible cumulative effects and serious sequelae that might occur after concussion.

Criteria for returning to sport include that an athlete with LOC or amnesia should not return to play the same day, and no athlete should be returned to play until completely asymptomatic, both at rest and with exertion (Sturmi et al., 1998). Wojtys et al. (1999) reviewed the return to play classifications in terms of same day or not the same day. The criteria for returning to play the same day include signs and symptoms that clear within 15 minutes or less, both at rest and with exertion; normal neurologic evaluation; and no LOC. On the other hand, the cases that should not return to play after concussion include those with signs and symptoms that do not resolve within 15 minutes at rest or with exertion and any LOC.

Cantu's, the 'Colorado Medical Societies', and the AAN's guidelines for returning to play following concussion are based on the grade of concussion and previous history of concussion sustained by an athlete. A first concussion of Grade 1 may indicate return to play the same day, but a second Grade 1 or multiple Grade 1 may suggest no return to play for 3 months (Colorado) or until next season (Cantu).

A person with a first time concussion of Grade 2 and Grade 3 may not return to play the same day. An athlete with a second Grade 2 concussion may return to play in 1 month (Cantu and Colorado) or after 2 weeks if asymptomatic (AAN). In a case of multiple concussions in the same season, the remainder of the season should be terminated (Cantu and Colorado).

An athlete with a first-time concussion of Grade 3 may return to play in 1 month. A second Grade 3 concussion should indicate termination of the season (Cantu and Colorado).

The Colorado Medical Society and AAN guidelines recommended that athletes with any loss of consciousness be transported to a medical institution for further evaluation.

As an alternative method, Guskiewicz et al.'s studies implied that measuring postural stability might aid clinicians in making a decision regarding when an athlete can safely return to play, although there were no significant associations between the results of these tests and neurocognitive functions (Guskiewicz, 2001; Guskiewicz et al., 1997; 1996; Ingersoll & Armstrong, 1992). Furthermore, this method requires expensive equipment, often not available in sports.

Recently, another method to measure injury severity and to guide return to play was suggested by McCrory, Ariens, and Berkovic (2000). This method uses both the number of postconcussive symptoms and their duration. The system itself has not been fully described, but might be worthy of further research to investigate its validity.

Sideline assessment of concussion

The recommended sideline evaluation of all athletes suspected of having sustained concussions includes a general neurologic exam (pupillary reflexes, visual fields and gross vision acuity, balance, gait, coordination, reflexes, sensations, and muscle strength), mental status testing (orientation to time, place, person, and game situation; posttraumatic and retrograde memory regarding game and pre-game activities; and concentration) and exertional provocative maneuvers such as a short distance dash, push-ups, and sit-ups (Kelly & Rosenberg, 1997; Maddocks, Dicker, & Saling, 1995). The sensitivity and specificity of these tests are limited. However, orientation tasks (ask about person's name, age, date of birth, place), serial sevens (100 – 7 = ?, 93 – 7 = ?, ….), and the standard Romberg tests have been studied for their sensitivity and specificity in the diagnosis of concussion.

Maddocks et al. (1995) have evaluated the sensitivity of traditional orientation items (e.g. What is your name?) and questions relating to recently acquired information (e.g. Which team did we play last week?) in the diagnosis of concussion suffered in athletes. They found that items evaluating recently acquired information (e.g. which team did we play last weekend? or which team won?) were more sensitive in the assessment of concussion (McCrory, 1997) than standard orientation items. Yarnell and Lynch had already suggested this in 1973.

The serial sevens test, one of the concentration test items used in mild concussions, has been evaluated for its validity. That study showed that the percentage of uninjured high school athletes successfully completing serial sevens is too low (52%) to make the test useful for the evaluation of concussion (Young, Jacobs, Clavette, Mark, & Guse, 1997). The study suggested that utilizing the item of 'month of year reverse' may be better for examining concentration. However, this study did not test concussed athletes.

The Romberg test involves asking the athlete to stand with the feet together and the arms at the sides with their eyes closed. This should not result in any increase in postural sway. This test has been studied by Riemann (1997) for its validity in concussed athletes. Statistical analysis revealed that the original Romberg test (or standard) may not be sensitive enough to detect deficits in postural stability following a concussion. The study suggested that clinicians should consider using other tests, such as the single leg Romberg test or a tandem stance test rather than the Standard Romberg test, during sideline or assessment of mild head injury.

The Standardized Assessment of Concussion (SAC) has been proposed as a means of detecting concussions in sports and rendering recommendations for return to play. The SAC was developed using concussion management guidelines suggested by the

Colorado Medical Society and the American Academy of Neurology practice parameters. The SAC consists of standardized questions for examination of mental status; 1) the athlete's orientation, 2) immediate memory, 3) concentration, 4) delayed recall, and for exertional tests and neurologic examination. The mental evaluation is based on a scoring system. The SAC is used to detect mild forms of concussion, takes approximately five minutes to administer and is designed for use by a non-neuropsychologist with no prior expertise in psychometric testing (McCrea, Kelly, Kluge, Ackley, & Randolph, 1997; Wojtys et al., 1999). Although it has several advantages on the sidelines of sporting events, it is not useful when baseline data (prior test data) are not available for comparison.

Postconcussive syndrome

Cerebral concussion with persistent symptoms was described by Boyer in 1822, Astley Cooper in 1827, and Dupuytren in 1822 (Evans, 1994). The earliest use of the term "postconcussion syndrome" was in 1934 (Evans, 1994). There is no universal agreement on the definition of postconcussion syndrome. Postconcussive syndrome is defined as a persistent collection of symptoms that can include cognitive complaints, physical complaints, and psychological complaints (or behavioural and affective symptoms) following a concussion (Evans, 1994; Bernstein, 1999; Leblanc, 1999). This is widely accepted and used in most of the literature on postconcussion syndromes. Rutherford (1989) divided the common postconcussion symptoms into early and late symptoms. The early symptoms (minutes to hours according to Kelly & Rosenberg, 1997) are what the patient complains of immediately after regaining full consciousness or the following morning. They include headache, dizziness, vomiting, nausea, drowsiness, and blurred vision. The late symptoms (days to weeks according to Kelly & Rosenberg, 1997) are those that are reported a few weeks later such as headache, dizziness, irritability, anxiety, depression, insomnia, fatigue, and problems of memory, concentration, hearing and vision. It has been estimated that postconcussion symptoms are experienced by 50 to 80 % of concussed adults following mild head injury (Binder, 1997; Alves, Coloban, O'leary, Rimel, & Jane, 1986). Alves et al. (1986) found that the most frequently reported symptoms at discharge from the hospital were headaches (45.8%), dizziness (14.2%), memory problems (13%), and weakness (10.4%). Often these symptoms occur in the absence of any objective neurological abnormalities (Willberger, 1993).

Although the causes and recovery rate of postconcussion syndrome remain controversial, postconcussion symptoms, associated with uncomplicated minor head injury, usually disappear within days or up to three months (Mttenberg & Strauman, 2000; Hinton-Bayre et al., 1999; Barth, Diamond, & Errico, 1996; Alves, Macciocchi, & Barth, 1993; Gordon, 1990; Levin et al., 1987; Gerberich et al., 1983). Jagoda and Riggio (2000) observed that the best prognosis in postconcussion symptoms was for well-motivated young male patients (Barth, Freeman, & Winters, 2000), such as athletes. However, Mittenberg, DiGiulio, Perrin, & Bass (1992) found that posttraumatic symptom frequencies were unrelated to the patient's age, gender, or occupational status.

Although the causes of postconcussion syndrome are controversial (Barth et al., 1996), several plausible theories exist. The primary causes of postconcussion syndrome may be related to cerebral dysfunction and structural anomaly (Mittenberg & Strauman, 2000; Szymanski & Linn, 1992; Gordon, 1990). Also, psychological factors, premorbid substance abuse (e.g. alcohol), monetary compensation (e.g. financial settlement), and personality factors (Mittenberg & Strauman, 2000; Szymanski & Linn, 1992; Gordon, 1990; Alves et al., 1986, 1993; Binder, 1986) are reported to play a role in the syndrome.

Head injuries in sports

Head injuries are common in all contact/collision sports. Especially, a high incidence of head injury occurs in contact/collision sports, such as football, ice hockey, boxing, and martial sports. However, a prospective hospital study of 586 patients found that only 8% of patients with mild head injury sustained their injuries during sports activities (Alves, 1993). This injury rate may possibly be underestimated because most athletes who have had a mild head injury do not seek medical personnel (Warren & Bailes, 1998). According to the US Centers for Disease Control and Prevention, there are 300,000 sport-related concussions per year in the US (cited by Sturmi et al., 1998; Kelly, 1999).

Dick (1994) has summarized head and neck injuries in collegiate athletics using the NCAA Surveillance System for a three to six year period (from 1984 to1990). The rate of head injury (the percentage of athletes injured) was from 5.4% (ice hockey) to 2.5% (men's basketball) among the nine sports (football, baseball, field hockey, ice hockey, men's and women's lacrosse, men's and women's soccer, men's and women's basketball, women's softball, and wrestling). Ice hockey, football, and field hockey recorded higher injury rates than other sports. The most common type of head injury in this study was concussion, accounting for at least 60% in each of the sports monitored.

Fewer than 10 percent of concussions resulted in loss of consciousness (Cantu, 1998a). Also, Ruchinskas, Francis, and Barth (1997) suggest that, among reported injuries, the chances of any athlete incurring mild head injury are generally between 2% and 10%, but range as high as 91% for equestrian accidents. The estimated rate of mild traumatic brain injury, as described in the literature, is variable: football (2-20%); soccer (4-22%); boxing (1-70%); rugby (2-25%); and equestrian (3-91%) (Ruchinskas et al., 1997). However, all of the information mentioned above has a substantial likelihood of underestimating the incidence of concussion because the cases without loss of consciousness tend not to be reported by athletes.

Due to the large number of participants in football, concussions are seen more frequently, approximately one in five high school football players each year in this sport (Gerberich et al., 1983). Also, more than 12% of those individuals who have concussions had two concussions in the same season. Athletes who sustain one concussion are at high risk to sustain another (Delaney, Lacroix, Leclerc, & Johnston, 2000; Barnes et al., 1998; Gerberich et al., 1983; Wilberger, 1983). Moreover, Powell and Barber-Foss (1999) have reported that of 23,566 reported injuries in 10 sports during the 3-year study period (1995-1997), 1,219 (5.5%) were concussions. Of all sports, football had the highest number (773 cases) and rates (63.4%) of concussion among high school athletes. More severe head injuries can also occur (e.g. subdural hematoma and intracranial injury).

Summary of research on concussion in sports

Although a number of studies of concussion/mild brain injury have been published using either animal or human models, the consequences of a concussion are still controversial due to methodological problems. Firstly, the application of the results of animal studies to humans has limitations due to the differences in terms of the size of neck/brain, injury mechanism (anesthetic state with fixed head, either by straight or angle forces), and the process/results of cognitive function tests. Secondly, even among human studies, differences with respect to the injury mechanism and the motivation of individuals to report concussions or their symptoms exist between general populations and sport populations. For example, a concussion in sport may lead to cessation of play, which is undesirable for most serious athletes. In contrast the reporting of symptoms after a motor vehicle accident can lead to monetary benefits that might motivate people to make such reports. Thirdly, there may be present misclassification between the control and experimental groups in some studies. If the assumption of concussion is based on athlete's self-reports, and athletes exhibit recall bias for several possible reasons. Also, because there is no universal agreement on the definition of concussion at present, leading to lack of comparability of groups. Fourthly, most studies were done with a small number of subjects. Fifthly, one more possible bias of the results of neuropsychological tests is when these are tested postinjury, because the duration of the effects of concussion are short and sometime occur later. Also, no clear norms exist for these neuropsychological tests. Sixthly, applying long-term or short-term effects of sport-related concussion to all sports has some limitations because there are unique differences regarding causes and situations of injury in each sport. For example, the mechanism of concussion in boxing is different from that in ice hockey. Additionally, there is a likelihood of underestimation of the incidence of concussion in sports because many studies of sport-related concussion were not conducted by direct observation and direct interviews at the injury site. Moreover, while a number of indications of severity of concussion and guidelines for return to sports have been designed and used on the sideline of sporting events, their validity is somewhat questionable. Validity of the screening process itself is made difficult by the lack of agreement of what constitutes a concussion, and particularly by the absence of a 'gold standard' for measuring concussion and concussion severity. To establish a uniform standard for measuring concussion and concussion severity, as well as guidelines for return to sport, as a first step, updated research on incidence of sport-related concussion with reliable/valid methods is necessary in each sport. Also, follow-up studies on the short-term and long-term effects of sport-related concussion are required, with consideration of the methodological issues mentioned above.

In summary, the literature on concussion and its definitions, its signs and symptoms, and the follow-up return to play guidelines is plagued with the uncertainty of what the neurological basis of concussion is and how it can be measured behaviorally in healthy and highly motivated athletes. The available validity evidence for the measures used is largely comprised of comparisons of group differences (for example, those with loss of consciousness and those without) in behavioral symptoms, some of which are difficult to observe and others of which are self reported. As a result, there is a certain lack of confidence in these measures and measurement systems.

According to Messick (1989), validity is a matter of degree, and refers to the quality of the inferences we can make based on the data, rather than the veracity of a measure itself. Put differently, what is ultimately of concern in the study of injury in Taekwondo in the quality of the decisions that are made to recommend 'return to play', stop play, or terminate competition based on the indications that are before us. Such decisions, and those of researchers to recommend rule changes, equipment changes, practice regimens, and playing strategies, should therefore be based on the best available evidence.

In the following papers, I have used medical by diagnosed, self-reported, and proxy (evidence of a head blow) measures of concussion in competition Taekwondo in an attempt to understand the risk and conditions under which participants can expect to put themselves at for (mild traumatic brain) injury in sport. While medical by diagnosed and observed (proxy) measures can be subjected to some examination of their reliability (a contribution to validity evidence, according to Messick, 1989), self-reported indicators are more difficult to study, especially in athletes who are highly motivated to compete and who may see some symptoms as a sign of weakness (thus being reluctant to report them).

2. Martial arts injuries

There are a number of styles in the martial arts: Taekwondo, Karate, Kung fu, Kendo, etc. These sports vary in the degree to which certain levels of body contact. For instance, head blows are legal, intensely practiced, and promoted for the awarding of points in these sports. Injuries are sustained not only in training, but also in tournament competition. Birrer and Halbrook (1988) conducted a five-year national survey of martial arts in the United States. Seventy-four percent of the reported injuries involved the lower and upper extremities, and 95% were mild to moderate in nature. Most injuries were contusions/abrasions (36%), sprains/strains (28%), dislocations/fractures (15%), and lacerations (14%). Moreover, Birrer and Birrer (1983) observed that unreported injuries in the martial arts during tournament situations and practice sessions were as high as 63%, including fractures, dislocations, and concussions. Injuries were recorded by an interviewer, who observed practice and tournament situation sessions, but these injuries were recorded as "unreported". The reason for unreported injuries in the martial arts includes confusion about the definition of injuries and ignorance on the part of the players (study participants) about what constitutes an injury. The definition of injury is a very important factor in the estimation of injury frequency because accurate numerators (injury data) are collected by the case definition.

Concussions and other injuries in Taekwondo competitions

Taekwondo is typically associated with minor injuries, particularly contusions, sprains, and strains of the lower and upper extremities. However, more apparently serious injuries in the head region do occur (Birrer, Birrer, Son, & Stone, 1981).

All matches permit full body contact. The athletes are allowed to kick the head and all parts of the body above the belt, but they are not allowed to use their fists against the head. The competitors wear head-gear, chest-gear, arm and shin pads, and a groin protector. A mouth guard is still not mandatory in competition Taekwondo.

In 1983, during the 6th Taekwondo World Championship with 346 competitors, more than 4% of the competitors were admitted to hospital (Siana, Borum, & Kryger, 1986). The majority of the severe injuries were to the head and neck. One case of head concussion occurred. All injuries were caused by direct blows. The competitors wore chest gear, arm and shin pads, and a groin protector, whereas the head was unprotected.

Nine out of 11 injured athletes with injuries to the head and neck region were using mouthguards. The types of injury in this competition included fractures (seven cases), contusion and lacerations (five cases). Results from this study are difficult to compare to other studies due to a lack of athlete or time-exposure data.

Martine and coworkers recorded sports injuries at the 1985 Junior Olympics (ages were not mentioned) (Martine, Yesalis, Foster, & Albright, 1987). Sixty-one athletes participated (12 females and 49 males). The total numbers of injuries were five (8.3 (one case) injuries/100 participants for females and 8.2 (four cases) injuries/100 participants for males). Eighty percent of the total injuries were mild and twenty percent were moderate. The major types of injury were laceration (25%) and contusion (10%). The percent of significant injuries to the body was sixty percent in the head, neck, and trunk. No detailed injury data were available in this report.

In the 1988 Taekwondo US Olympic Team Trials involving 48 men and 48 women (age from 15 to 37 years), Zemper and Pieter (1989) recorded the rate of injury that received medical attention in terms of 100 athlete-exposures, or 100 minutes of competition fighting. For men, 12.7 injuries/100 athlete-exposures were reported, while women had 9.0 injuries/100 athlete-exposures. Of these reported injuries for both men and women, 15% resulted in the athlete missing one or more days of practice or competition after the injury. The rate of head concussion was 0.5 injuries/100 athlete-exposures in men, and 0.5 injuries/100 athlete-exposures in women (one case for each gender). This study did not mention the injury mechanisms involved in concussion. However, the most predominant mechanism for all injuries was evenly split between delivering and receiving a blow (35% each) in women, while it was predominantly receiving a blow (63%) for men. The women tended to be injured more during offensive moves, while the men were injured more often as a result of defensive moves. The foot and the head were the most frequently injured body parts. Contusion was the predominant type of injury (73% for women and 63% for men). Among the more serious injuries, men recorded four fractures.

In a study by Oler et al., (1991) of two National US Taekwondo tournaments (one senior and one junior level), injuries to the head and neck were the most common reported to the medical personnel. Twenty-nine of approximately 700 adult competitors sustained head or neck injuries (approximately 41/1,000 participants) and sixty of approximately 3,000 junior competitors (approximately 20/1,000 participants) sustained injuries. Three cases of concussion occurred in adult competitors (all cases had loss of consciousness), and nine cases of concussion occurred in junior competitors (only one case had loss of consciousness). The mechanism of concussion and specific athlete-exposure data were not reported in this study.

Taekwondo injury at the elite level was studied by Pieter and Lufting (1994) at the World Taekwondo Championships in 1991. The purpose of this study was to assess acute injuries, particularly serious injuries such as concussions and fractures, which lead to time-loss from participation of one day or more. A total of 433 competitors (160 women and 273 men) from 49 countries participated in the competition. The injury rate was 26.4 injuries/1,000 athlete-exposures (A-E) (12.9 injuries/1,000 A-E for women and 34.4 injuries/1,000A-E for men). Male athletes had a higher injury rate than female athletes in this tournament. The injury rate for concussions was 3.2 concussions/1,000 A-E (one case) for women and 15.3 concussions/1,000 A-E (eight cases) for men. The concussion rate in males at the World Taekwondo Championships was 2.5 times higher than that of the US male athletes competing at the national championships (6.1 concussions/1,000 A-E). Also, the concussion rate was three times higher when compared to American college football (1.7 concussions/1,000 A-E) (Zemper & Pieter, 1994). The mechanisms of serious injuries included delivering a blow (3.2 injuries/1,000 A-E for women and 1.9 injuries/1,000 A-E for men) and receiving a blow (6.5 injuries/1,000 A-E for women and 26.7 injuries/1,000 A-E for men). Although this study did not report the exact mechanism of injury for the concussions, the authors mentioned that concussion might be related to concrete floors that were present. The resultant high concussion rate at the 1991 Championships could thus be due to falls instead of kicks to the head. Further research is required to verify this relationship between the incidence of head concussion and the facility characteristics (concrete or hard wood floor and foam mat). Women had a higher injury rate for fracture than their male counter part (6.5 injuries/1,000 A-E for women and 1.9 injuries/1,000 A-E for men).

Several studies have been conducted to identify injury and its mechanism in competition Taekwondo by self-report. However, these studies have not looked at the specific Taekwondo techniques causing injuries. Pieter, van Ryssegem, Lufting, and Heijmans (1995) observed the situation and mechanism of injury, and present the exact kicking technique involved for injuries incurred at the 1993 European Taekwondo Cup (30 women and 67 men). The total injury rate for women was 96.5 injuries/1,000 A-E, and for men, it was 139.5 injuries/1,000 A-E. The most predominant type of injury was contusion for both genders (87.7/1,000 A-E for women and 69.8/1,000 A-E for the men). Attacking with a roundhouse kick most often led to an injury for both genders

(61.4/1,000 A-E for women and 58.1/1,000 A-E for men). Delivering a roundhouse kick was the major cause in the men (46.5/1,000 A-E). In the women, receiving a roundhouse kick and receiving a spinning kick causes the most injury (35.1/1,000 A-E for each). The results of mechanisms in this research are different from the study at the 1988 US Olympic Team Trials. At that competition, the most predominant injury mechanism was delivering and receiving a blow (35% each) in women, while it was predominantly receiving a blow (63%) in men. The injury rate for concussion was 8.8/1,000 A-E for women and 15.5/1,000 A-E for men. The main cause of concussion was receiving a blow with both the roundhouse and spinning kicks. Noticeably, the weight categories were divided into four divisions in this tournament, whereas other competitions were divided into eight divisions. Due to a large weight gap in the same weight division, there could have been a height difference between many competitors. A taller competitor can kick his or her opponent's head area more easily. Although they did not test for a relationship between the injury rate and different weight division, the data showed that the total injury rate was increased in the higher weight categories for the men. Further research is needed to examine other possible risk factors such as height, weight, and skill level causing concussion in Taekwondo competitions.

Pieter and Zemper (1997; 1999) reported the rates of injuries sustained during Junior Taekwondo competitions from the 1989 to 1990 in US. A total of 3,341 boys and 917 girls (ages, 6-16 years) were involved in two US National Championships. No difference was found between boys (58.3/1,000 A-E) and girls (56.6/1,000 A-E) in the total injury rate. Significant differences in injury rates by body area were found, with the lower extremities (21.8/1,000 athlete-exposures) ranked first. Unblocked attacks were the major cause of injury in both boys and girls. There was a distinct trend toward increasing injury rate per 1,000 A-E with increasing weight categories and age for boys and girls. There were 31 cases (5.1/1,000A-E) and seven cases (4.6/1,000 A-E) recorded of concussion for boys and girls, respectively. Even though this research did not examine the specific mechanism of concussion, receiving a blow (32.3/1,000 A-E); delivering a blow (12.9/1,000 A-E); impact with the floor surface (4.7/1,000 A-E); and other mechanisms (3.6/1,000 A-E) were identified. A large proportion of injured athletes did not or could not block attacks.

Feehan and Waller (1995) examined the pattern of injuries sustained by Taekwondo competitors in the 12 months before a competition, and how previous injury might affect performance in competition (fight wins and losses). They found that the injury prevalence was high (males 69%, females 67%) in both genders. The most common site of injury was the upper or lower leg (35%), followed by the ankle or foot (16%). The head and neck were injured in 11% (5% concussion) of the cases. No significant associations between prior injury and tournament outcome were found.

In competition Taekwondo, many of the powerful kicks can cause injuries. Serina and Lieu (1991) observed that injury potential could be evaluated through thoracic compression and viscous criterion models. These models predict a significant probability of serious injury with all kicks, with thoracic deflections from 3 to 5 cm and peak viscous tolerance values from 0.9-1.4ms^{-1}, when no protective body equipment is used.

Zemper and Pieter (1994) summarized that the incidence of concussions in Taekwondo athletes at eight major US Taekwondo tournaments between 1988 and 1990 (the 1988 US Olympic Team Trials, the 1989/1990 US Senior National Championships, the 1989/1990 US Senior Team Trials, the 1989/1990 US Junior National Championships, and the 1989 World Junior Championships), involving 5,682 competitors and a total of 5,566 bouts. Junior competitors were aged 6-17 years and senior competitors were aged 18 years and older. There were 58 concussions. The total concussion rate was 5.2/1,000 A-E or 1.1/1,000 minutes of exposures (M-E). A total concussion rate for Juniors was 5.3/1,000 A-E or 1.4/1,000 M-E, and for Seniors, it was 5.1/1,000 A-E or 0.7/1,000 M-E. Severity of concussions ranged from very mild, involving post-bout headache following a direct blow to the head (Nelson Grade 0), to severe, (Nelson Grade 4) involving extended loss of consciousness, retrograde amnesia and, in one case, seizures. There were 11 cases of Grade 0 concussion recorded, 36 cases of Grade 1 or 2, eight cases of Grade 3, three cases of Grade 4. All of the Grade 3 and 4 concussions occurred in males. Males had a somewhat higher rate of concussion than females, while juniors and seniors had about the same rate based on athlete-exposures. The present study's age range was quite broad. For comparable purposes to other sports, the age levels should be broken down into several groups, such as children (ages), middle school (ages), high school (ages), and college or adult (ages and over). Future studies should consider specific age groups with other possible risk factors in sustaining brain concussion.

Pieter and Zemper (1998) analyzed that the exact conditions for concussion occurring in competitions from the 1989, 1990, and 1991 US National Senior Taekwondo Championships, and the 1988, 1989, and1990 US Taekwondo Team Trials. A total of 1,665 men and 742 women competed in these competitions. The men sustained more concussions (7.0/1,000 A-E) than the women (2.4/1,000 A-E) did. The main mechanism of injury was receiving a blow without blocking the attack for the women (100%) and men (91.7%). For the men, one athlete sustained an injury while attempting to block an attack and two athletes incurred concussions associated with falling. The female concussions were all mild in nature, but 16.7% of the concussions in the males were of a severe nature. All of these reported incidence rates of concussion are probably minimum rates since the concussed athletes who did not show obvious signs of concussion such as loss of consciousness or being knocked down after a blow, were not recorded.

Risk factors for Taekwondo injuries

Concussion:

Several hypotheses regarding risk factors for concussion in competition Taekwondo have been formulated. Receiving a blow to the head area has been shown to be a major risk factor for head concussion in men and women adult Taekwondo athletes (Pieter & Zemper, 1998; Pieter et al., 1995; Pieter & Lufting, 1994). Although it is an obvious factor for causing concussion, the relationship between head blows and concussions has not been studied in detail. Another hypothesis is that athletes can sustain a cerebral concussion as a result of a fall after being hit (Pieter & Zemper, 1998; Pieter & Lufting, 1994). Therefore, the floor surface at the competition area may be related to the incidence of concussions. However, this conclusion is controversial because there is no clear evidence, such as videotape records, for this hypothesis. Another possible situation for this may be the direct kick as a primary cause for concussion, with the fall on the floor being an additional factor. For instance, contact with the floor may influence the severity of the injury. Oler et al. (1991) suggested that factors contributing to injuries in

Taekwondo are rules that promote/allow head contact; inadequate training techniques; and inadequate safety equipment. The relationships between each of these risk factors mentioned above and concussion have not been studied. Therefore, these issues and others, such as the relationship between competitor's height/weight and the sparring type of the participants, remain to be investigated in future studies.

Summary for concussions in Taekwondo competitions

In competition Taekwondo, injury incidence rates have been reported by several researchers. On average concussion is sustained in less than or equal to one percent per tournament, for all age groups. These incidence rates of concussions may underestimate the true incidence in competition Taekwondo due to a lack of reporting mild cases or incomplete understanding of concussion by competitors. Although there are several proposed hypotheses with respect to risk factors causing concussion, there are limited direct studies on this matter. To respond to the limitations discussed earlier, further research is needed, particularly re-examining the incidence of concussion following direct blow to the head (by direct contact) and to the other body regions (by indirect contact or whiplash) in competition Taekwondo. It could be important to provide a more reliable method of determining the mechanism of injury than observation in real time and self-report. Furthermore, the effects of concussion on short-term and/or long-term brain function remain to be answered in future studies in this sport.

The developing research program that is presented in this dissertation is designed to address some of the shortcomings in the competition Taekwondo literature. First, a study of the 1999 World Taekwondo Championships was conducted to examine injury rates (including mild, moderate, and serious injuries) using explicit exposure data. Secondly, a videotape analysis of the mechanisms of injury provided a protocol for a more reliable assessment of potential injury context and mechanism than could be gained through self-report. Thirdly, a systematic review of the incidence of concussion in contact sports was undertaken using inclusion and exclusion criteria that result in a more valid estimation of incidence rates. Finally, a study of a large competition Taekwondo tournament in South Korea, was conducted using the methods developed in the previous studies.

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CHAPTER 2

Injuries at the 14th World Taekwondo Championships in 1999[1]

INTRODUCTION

Taekwondo is a Korean martial art that has grown into a new worldwide sport. Its origin dates back at least 1,000 years and its modern style has evolved rapidly since the1950s. Today, Taekwondo is practiced in at least 160 countries, with approximately 30 million people, and 120 nations, holding official membership in the sport's major organizing body, the World Taekwondo Federation (WTF). In recent years, Taekwondo has become a modern sport with the heritage and the sport science maintained. Due to its particular purposes, involving both physical and mental training, Taekwondo was established as part of the regular curriculum of primary schools through colleges in Korea as well as in other countries.

The World Taekwondo Federation has organized international Taekwondo competitions such as the World Taekwondo Championships since 1973. Competition Taekwondo or Olympic Taekwondo is a free-sparring full contact sport using bare hands and feet, in which athletes wear protectors for the head, chest, groin, arm and shin and, optionally, a mouthguard under WTF rules.

Although the World Taekwondo Championships have been held for over two decades, there are limited studies on injury incidence in Taekwondo. The first study was conducted by Siana, Borumm, and Kryger (1986) at the 1983 World Taekwondo Championships (6th). This study listed the injuries sustained in absolute numbers and

[1] A version of this chapter has been published. Koh, De Freitas, & Watkinson 2000. International Journal of Applied Sports Sciences, 13:33-48.

percentage of total serious injuries reported. Because it did not report injuries relative to exposure data, comparison to other similar studies is difficult. Another study was performed by Pieter and Lufting (1994) at the 1991 World Taekwondo Championships. They recorded only acute serious injuries such as concussions, fractures, and dislocations that usually lead to discontinuing or terminating the match or practice. Neither study reported overall minor and mild injuries. As well, none of these studies' results were tested statistically. Therefore, the purposes of present study were to measure incidence, frequency, type, situation and mechanism, and severity of acute injuries and to compare the incidence of injury among male and female athletes competing in the 1999 World Taekwondo Championships (14^{th}).

METHODS

Data were collected at the 14^{th} World Taekwondo Championships on June 2-6, 1999 in Edmonton, Canada. A total of 563 athletes (233 females and 330 males) from 66 countries participated in the tournament and ranged in age from 15 to 38 years.

When an injury was sustained during the tournament, the injured athlete was assessed by the tournament physicians or athletic trainers or team doctors. Injury data were collected by an open-ended simple check-off form (interview format, Appendix B) developed by the author. The form described gender, weight division, time of injury occurrence, injury situation, injury mechanism, techniques that caused the injury, previous injury history, and injury diagnosis (including anatomical site, type, and severity of the injury, referral, and management of injury). The injury forms were completed at the time of injury treatment by the tournament physicians and nurses or by team physicians and athletic trainers. Prior to the commencement of the tournament, all research project staff including all medical personnel, were informed of the research purposes, definitions of injury and injury severity, procedures of the research project, and recording injury forms.

Exposure data were gathered from records of actual bouts completed by the author. Each bout contained three rounds of three minutes (a total of 9 minutes). In cases where bouts were not completed (e.g. due to an injury), the rounds completed and time when the bout was stopped were noted. Injury incidence rates (or cumulative incidence) were calculated using the basic rate formulas: (1) (number of injuries / number of athlete-exposures) x 1,000 = number of injuries per 1,000 athlete-exposures; (2) (number of injuries / number of minutes of exposures) x 1,000 = number of injuries per 1,000 minutes of exposure. This calculation has been utilized by Zemper and Pieter (1994). One athlete-exposure refers to one person being exposed to the possibility of sustaining an injury. During one Taekwondo bout, there are two athletes competing at the same time (Pieter & Lufting, 1994). The study was reviewed by the Research Ethics Board of the Faculty of Physical Education and Recreation and assessed as meeting the standards of the Canadian Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans.

Definitions used in the present study were as follows.

1) Injury:

Any acute injury sustained while fighting (sparring) Taekwondo during the Taekwondo competition that results in a player's missing the remainder of the match and/or requires a player to consult a health professional (Voaklander, Saunders, Quinney, & Macnab, 1996).

2) Injury severity:

Mild: Any acute injury sustained while engaging in Taekwondo during the tournament that **does not result in a player missing** the remainder of the fight/bout and does not affect active participation. Injuries that do not restrict active participation include contusion, minor sprains and strains and certain finger injuries such as fractures since closed finger fractures require only taping.

Moderate: Any acute injury sustained while engaging in Taekwondo during the tournament that **does not result in a player missing** the remainder of the tournament but leads to some disruption (less than 100%) of participation. Injuries that disrupt participation include a sprained ankle or foot injury, which can modify the player's fighting strategy.

Severe: Any acute injury sustained while engaging in Taekwondo during the tournament that results in a player **missing** the remainder of match and/or **requiring urgent** referral to a hospital. Injuries with no further participation (severe cases) include brain concussions regardless of the grade, bleeding from the face, etc.

3) Kelly's (1991) definition and severity of brain concussion were adapted in this study.

4) Injury situation and mechanism

Injury situation refers to what the injured athlete or his/her opponent was executing such as delivering or receiving a kick/punch at the time of injury.

Injury mechanism refers to the cause of injury such as contact (e.g. contusions and fractures) or non-contact (e.g. sprains and strains).

The Chi-square test was employed to determine differences in total injury rate between males and females. Differences in injury rates specific to body regions (head, face, and neck; upper body; and lower body) by gender were also tested by Chi-square statistics (Glass & Hopkins, 1996). All analyses were performed with the alpha level set at less than or equal to 0.05. In addition, a Bonferroni correction was performed for each specific body region (Family wise significance level at 0.02). For multiple injury cases (e.g. an athlete has had two or more injuries during the tournament), the most serious injury was recorded on the injury case form.

RESULTS

A summary of the injury and exposure data is presented in Table 2-1. Tables 2-2 to 2-8 show distributions of injuries by the body region, injury type, situation, mechanism, technique, weight division, and severity, respectively.

There was no difference between males and females in total injury ($p = 0.101$). The injury rates of specific body regions: head and neck, upper body, and lower body between genders were analyzed using chi-square analyses. Only the lower body region was found to be significantly different by gender ($p = 0.012$). While the head and neck region appeared to sustain significantly different injury rates by gender ($p = 0.042$), this was not significant when a Bonferroni correction was applied. No difference between genders was found in the injury rate of the upper body region.

Overall, the total injury rates were as follow: the head and neck including face (total 20 cases) 28.52 injuries/1,000 A-E for males, 7.11 injuries/1,000 A-E for females; upper body including arms, trunk, and back (total 28 cases) 33.56 injuries/1,000 A-E for males, 18.96 injuries/1,000 A-E for females; and lower body including legs, pelvis, and hips (total 61 cases) 71.1 injuries/1,000 A-E for males, 63.98 for females.

In this study, mild injury was most frequent in both genders as expected. Surprisingly, the severe injury was more prevalent than moderate injury in males. Females showed a tendency for less severe injuries. Among severe injury cases, the head, face, and neck area showed the highest injury frequency (12 out of 26 cases), followed by the lower body area (9 cases), and upper body area (5 cases).

All injured athletes in competition were assessed and treated by tournament physicians, team doctors, or other types of medical personnel. Fifty-eight percent of the injured athletes received the application of therapeutic modalities such as ice and ultrasound, 19% immobilization, 12% tapings, 1.8% sutures, and other types of first aid (bandage and rest). In addition, some athletes received multiple treatments, e.g., both ice and tape.

DISCUSSION

Definitions of injury, injury severity, and concussion used in this project were different from Pieter and his colleagues' Taekwondo injury studies (Pieter & Lufting, 1994; Pieter & Zemper, 1998). For this study, the definition of injury was more sensitive (i.e., any disruption or discomfort as a result of competition) because athletes continuously participate with injuries for which they may not lose any time, but may participate at less than 100% (Martin, Yesalis, Foster & Albright 1987). Also, the indicator of injury severity used in our study was limited to the period of tournament participation and did not include any measure of long-term time loss. Thus it may be more accurate than measures which require monitoring over a period of time.

Total injury frequency in male athletes was almost two times higher than in female athletes, though the total injury rate did not differ between genders when total participants in each gender were taken into account. The severe injury rate for this study was similar to that found by Pieter and Lufting (1994) but lower than Pieter, van Ryssegem., Lufting and Heijmans's 1995 study. One possible explanation for these differences is due to the different type of competition. The World Taekwondo Championship was based on a single elimination tournament, whereas the European Taekwondo Cup at which the 1995 data were collected was based on a round-robin tournament. In round-robin tournaments, the number of athletes-exposures (i.e. the number of matches) per athlete was higher than in single elimination tournaments. It is reasonable to expect that more injuries occur with more exposures per athlete.

During the 6th World Taekwondo Championship in 1983 (Siana et al., 1986), there were nine cases related to the head, face, and neck regions. Most of these were severe injuries including fractures (5 of 9 cases were facial bone fractures) and a concussion. At this 1983 tournament, the head was not protected since usage of the head protector did not become mandatory until 1985. In comparison to the 1983 World Taekwondo Championship, the present study recorded a lower frequency of facial fractures (2 cases) but more cases of brain concussion. This may indicate that the head protector reduces the severity of facial injuries, but not brain concussions. It is commonly believed that a helmet may absorb energy upon impact and distribute the impact over the skull and over a longer period of time (Lloyd, Lauderdale, & Betz, 1987). Thus, wearing headgear may reduce injury severity when the head hits the mat after impact (Pieter & Zemper, 1998). Unfortunately, however, the helmet worn in Taekwondo seems not to protect against concussion from a kick such as a roundhouse kick or a spinning kick. The roundhouse is known to produce higher accelerations of the brain (Pieter & Zemper, 1998) that can lead to concussion when force is loaded to the jaw and head region. Also, acceleration forces are magnified when the force is applied to a soft object (Halliday, 1999) such as rugby headgear (McIntosh & McCrory, 2000) that is similar to Taekwondo headgear or foot protector (Schwartz et al., 1986). While headgear may appear to disadvantage athletes with respect to head concussion, the helmet reduces or prevents other types of injuries such as fractures.

The most frequently injured body part was the foot in both males and females, confirming the results reported by Pieter and Zemper (1995) from six different Taekwondo competitions in the United States. The present study demonstrates lower injury rates of the foot compared to Pieter and Zemper's study (1995), however, especially for the female athletes. Probably this is due to the higher skill levels of the athletes in the current study. Typically, an athlete who has poor kicking skill tends to kick an opponent's bony prominence instead of the legal target areas and to execute kicking techniques at inappropriate times.

A dominant injury mechanism of the foot was by delivering a kicking attack in both studies. During competitions or sparring, the most popular kicking technique is the round or roundhouse kick because it can generate maximal power, speed, and contact sounds. When performing this kicking skill, a legal contact area of the foot is below the malleolus (the anklebone) which is unprotected, making the foot susceptible to injury. Pieter and his colleagues (1995) have indicated a concern for adapting the foot protector in order to reduce foot injuries in Taekwondo competitions. This issue however, needs further consideration because it may protect the attacker more than the defender. Moreover, adapting the foot protector may increase other types of injuries such as head concussion. Schwartz et al. (1986) have demonstrated that the foot protector increased peak accelerations imparted to the head when dummies were used. They concluded from the experiment that violent accelerations of the head by any means in boxing and other full contact sports produce head injuries. Furthermore, another study showed that a greater incidence of head injuries accompanied the reduction in hand injuries after the adoption of hand padding in Karate competitions (Johannsen & Noerregaard, 1988). In addition, Cretchley and coworkers (1999) reported that the absence of protective padding does not result in higher injury rates in Karate. To reduce foot injuries, utilization of other kicking techniques such as a back kick is one possibility. A competition rule, especially the point system (i.e. all skills score 1 point) should be changed to reflect technical difficulty and to reward the use of kicks that do not lead to injury. As well, mastering a kicking skill, and delivering a kicking skill to the legal areas and with appropriate timing are important considerations in practice.

Overall, the most frequent type of injury was contusion for both genders, followed by fractures in males, and sprains in females.

The number of concussions was much higher in males than in their female counter parts in this project. At the 1991 World Taekwondo Championships (Pieter & Lufting, 1994), the injury rates for concussions (15.27 injuries/1,000 A-E for males; and 3.23 injuries/1,000 A-E for females) were slightly higher in males and lower in females than at the 1999 World Taekwondo Championships. With genders combined, the total head concussion rate was about the same between the two studies. The concussion rates of those two World Taekwondo Championships were much higher than that in American high school football and wrestling in boys (0.59 and 0.25 injuries/1,000 A-E, respectively) (Powell & Barber-Foss, 1999). The predominant injury situation leading to concussion in this project was an unblocked received attack by roundhouse kicks (6 cases) and side kicks (2 cases). This finding is also consistent with the 1993 European Cup. It is assumed that the concussed athletes may not have anticipated the head attack from opponents or may have shortly lost focus at that moment, therefore they did not have a defense. In addition, the fin-weight category recorded the highest frequency of concussions in this project.

According to Pieter and Zemper's study (1998), most of the concussed athletes (70.83% in males and 50% in females) did not wear a mouth-guard. Chapman (1985a) showed that use of mouth-guard (especially a bimaxillary mouth-guard) aided in reducing the risk of orofacial injury and head concussion caused by mandibular impact (Chalmers, 1998). According to Chapman (1985b), a mouth-guard increases separation between the cranial base and the condyle, so that it lessens the risk of concussion following mandibular impact due to reduced mandibulo-cranial force transmission (Chapman, 1985a; 1985b). To reduce head concussions, as Pieter and Zemper (1998) suggested, usage of a mouth-guard should be mandatory in Taekwondo competitions. In addition, it has also been suggested that all athletes need to improve neck muscle strength as it can reduce the head free-motion after a blow to the front (i.e., whiplash injury) (Cantu, 1992). Unfortunately, the neck muscles are the least effective when a blow is received at the side of the face (i.e., roundhouse kick in Taekwondo) (Parkinson, 1982). None the less, improving neck muscle is better than nothing to reduce or prevent concussions.

Table 2-4 shows that delivering a blow by a kicking technique (offensive action) was the highest injury situation, followed by an unblocked receipt of a kicking skill (defensive action) in both genders. These results may be a function of the competition rule in Taekwondo. For example, an athlete who is constantly defending during a bout, is warned and penalized for inactivity. In other words, athletes are forced to fight offensively (i.e. accruing more attacks than an opponent) leading to injuries, even for the offensive player. The third frequent injury situation in males and females was blocking when receiving a kick. This finding indicates that blocking is not appropriate for defense when receiving a high force kick. To avoid or reduce injuries from sparring, one possible option is to alter fighting strategy to encourage more non-contact defensive actions such as defensive sparring steps, rather than using blocking skills against kicking skills.

As seen in Table 2-6, the most frequent technique leading to the injury was a roundhouse kick for both genders, followed by the side and front snap kicks for males and front snap kick for females. In females, the cutting kick also led to injury. The cutting kick caused substantial injuries in the past and has been banned in Taekwondo competitions. In order to reduce injury due to the cutting kick, the rule should be strictly enforced by the referees.

Interestingly, overall injury rates were highest for welter-weight and light-weight divisions (Table 2-7) in males and females, respectively. This is consistent with the 1991 World Taekwondo Championships (Pieter & Lufting, 1994) in males, though not in females. Once all eight weight divisions were combined into 4 weight divisions, (as done in Olympic games) the injury rate (not only absolute numbers but also relative numbers of total actual participants in each weight group) for the females increased with weight of the athletes. The same trend was not apparent for the males. This finding is the reverse of the 1993 European Taekwondo Cup (Pieter et al., 1995).

Fractures, including suspected fractures, account for the highest incidence among the severe injuries, followed by concussion. The foot, in the fin-weight division, sustained the highest fracture rate. The most frequent injury situation for incurring fractures was from delivering a roundhouse attack. An unblocked reception of a kick was also a common injury situation. Two cases occurred while the athlete tried to block a kick. Overall the fin and the light/welter categories incurred the most frequent severe injuries compare to other weight categories.

CONCLUSION

There are insufficient data on Taekwondo injuries at elite levels of competitions. The purposes of the present study were to measure overall acute injuries as a result of fighting and to compare the incidences of injury between genders at the 1999 World Taekwondo Championships. Although the absolute number of injuries in males surpassed that of the females, there was no difference in injury rates between male and female athletes. The most frequently injured body part was the foot and contusion was the most common injury type regardless of gender. The roundhouse kick caused the most injuries either through its delivery, or its unblocked reception. Welter-weights (males) and light-weights (females) recorded the highest injury occurrences. For females, there is a tendency for more injuries with increasing weight. Among the severe injuries, fractures accounted for the highest incidence followed by concussion. The incidence of concussion was the highest in fin-weight category.

In conclusion, despite the fact that several injury studies have been conducted, there are still unidentified possible risks in Taekwondo. Therefore, subsequent research on this issue is needed in future studies. Also, more research is required to verify possible associations between head concussion and other factors such as weight, weight loss, skill level, previous history of concussion, and to examine possible long-term effects on head concussion in this population.

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Table 2-1. Injury and exposure data for males and females 99 World Taekwondo Championships (99 WTCs)

	Males	Females	Total
Number of athletes	330	233	563
Number of matches	298	211	509
Athlete-exposure to the possibility of being-injured (2 per bout)	596	422	1,018
Minutes exposed (3 rounds x 3 minutes)	5,304	3,786	9,090
Reported injuries	72	38	111 (missing 1)
Injury rate per 100 participants	21.82 (95% CI: 17-27)	16.31 (95% CI: 12-22)	19.72 (95% CI: 17-23)
Injury rate per 1,000 athlete-exposures (A-E)	120.81 (95% CI: 96-150)	90.05 (95% CI: 65-122)	109.04 (95% CI: 91-130)
Injury rate per 1,000 minute-exposures (M-E)	13.57 (95% CI: 11-17)	10.04 (95% CI: 7-14)	12.21 (95% CI: 10-15)

Table 2-2. Distribution of 99 WTCs injuries by body region

Body region	Frequency M*	Frequency F*	Frequency Total	Injury rate per 1,000 A-E M	Injury rate per 1,000 A-E F	Injury rate per 1,000 A-E Total	Injury rate per 1,000 M-E M	Injury rate per 1,000 M-E F	Injury rate per 1,000 M-E Total
Head	6	2	8	10.07	4.74	7.86	1.13	0.53	0.88
Face	2	---†	2	3.36	---	1.96	0.38	---	0.22
Eye	1	1	2	1.68	2.37	1.96	0.19	0.26	0.22
Jaw	3	---	3	5.03	---	2.95	0.57	---	0.33
Nose	3	---	3	5.03	---	2.95	0.57	---	0.33
Throat	2	---	2	3.36	---	1.96	0.38	---	0.22
Elbow	4	1	5	6.71	2.37	4.91	0.75	0.26	0.55
Forearm	1	3	4	1.68	7.11	3.93	0.19	0.79	0.44
Wrist	2	1	3	3.36	2.37	2.95	0.38	0.26	0.33
Hand	4	1	5	6.71	2.37	4.91	0.75	0.26	0.55
Thumb	3	---	3	5.03	---	2.95	0.57	---	0.33
Chest	---	1	1	---	2.37	0.98	---	0.26	0.11
Abdomen	1	---	1	1.68	---	0.98	0.19	---	0.11
Finger	5	1	6	8.39	2.37	5.89	0.94	0.26	0.66
Hip	4	---	4	6.71	---	3.93	0.75	---	0.44
Thigh	4	2	6	6.71	4.74	5.89	0.75	0.53	0.66
Knee	7	4	12‡	11.74	9.48	11.79	1.32	1.06	1.32
Shin	6	5	11	10.07	11.85	10.81	1.13	1.32	1.21
Calf	---	1	1	---	2.37	0.98	---	0.26	0.11
Ankle	1	5	6	1.68	11.85	5.89	0.19	1.32	0.66
Foot	9	6	15	15.10	14.22	14.73	1.70	1.58	1.65
Toes	3	4	7	5.03	9.48	6.88	0.57	1.06	0.77
Total	**71**	**38**	**110**	**119.13**	**90.06**	**108.04**	**13.4**	**10.01**	**12.1**

* M: Males; F: Females.
† ---: Injuries were not occurred.
‡: Gender was not indicated.
Note: Publisher made typo errors in this table. The highlighted values here are the actual values found in this study. One missing case in this Table. Body regions not listed in this Table did not sustain injury in this tournament.

Table 2-3. Distribution of 99 WTCs injuries by type of injury

Injury type	Frequency			Injury rate per 1,000 A-E			Injury rate per 1,000 M-E		
	M*	F*	Total	M	F	Total	M	F	Total
Abrasion	3	---¶	3	5.03	---	2.95	0.57	---	0.33
Concussion	6	2	8	10.07	4.74	7.86	1.13	0.53	0.88
Contusion	20	19	40†	33.56	45.02	39.29	3.77	5.02	4.40
Laceration	3	2	5	5.03	4.74	4.91	0.57	0.53	0.55
Strain	7	3	10	11.74	7.11	9.82	1.32	0.79	1.10
Sprain	10	9	19	16.78	21.33	18.66	1.89	2.38	2.09
Dislocation	2	---	2	3.36	---	1.96	0.38	---	0.22
Fracture (?‡)	16	3	19	26.85	7.11	18.66	3.02	0.79	2.09
Other	4	---	4	6.71	---	3.93	0.75	---	0.44
Total	**71**	**38**	**110**	**119.13**	**90.15**	**108.04**	**13.4**	**10.04**	**12.1**

* M: Males; F: Females.
†: Gender was not indicated.
‡: Suspected fractures included as fracture.
¶ ---: Injuries were not occurred
Note: One missing case in this Table. Publisher made typo errors in this table. The highlighted values here are the actual values found in this study.

Table 2-4. Distribution of 99 WTCs injuries by the injury situation

Situation	Frequency			Injury rate per 1,000 A-E			Injury rate per 1,000 M-E		
	M*	F*	Total	M	F	Total	M	F	Total
Unblocked receiving a blow by a kick	19	7	27†	31.88	16.59	26.52	3.58	1.85	2.97
Blocked receiving a blow by a kick	14	6	20	23.49	14.22	19.65	2.64	1.58	2.20
Blocked receiving a blow by a punch	1	1	2	1.68	2.37	1.96	0.19	0.26	0.22
Delivering a blow by a kick	27	18	45	45.30	42.65	44.20	5.09	4.75	4.95
Delivering a blow by a punch	4	1	5	6.71	2.37	4.91	0.75	0.26	0.55
Fall	3	---‡	3	5.03	---	2.95	0.57	---	0.33
Fall by an opponent's pushing	1	---	1	1.68	---	0.98	0.19	---	0.11
Other	2	5	7	3.36	11.85	6.87	0.38	1.32	0.77
Total	**71**	**38**	**110**	**119.13**	**90.05**	**108.04**	**13.39**	**10.02**	**12.1**

* M: Males; F: Females.
†: Gender was not indicated.
‡: Injuries were not occurred
Note: One missing case in this Table. Publisher made a typo error in this table. The highlighted value here is the actual value found in this study.

Table 2-5. Distribution of 99 WTCs injuries by injury mechanism

Injury mechanism	Frequency M*	Frequency F*	Frequency Total	Injury rate per 1,000 A-E M	Injury rate per 1,000 A-E F	Injury rate per 1,000 A-E Total	Injury rate per 1,000 M-E M	Injury rate per 1,000 M-E F	Injury rate per 1,000 M-E Total
Contacted by receiving a blow	34	15	50†	57.05	35.55	49.12	6.41	3.96	5.50
Contacted by delivering a blow	23	12	35	38.59	28.44	34.38	4.34	3.17	3.85
Non-contact injury	10	10	20	16.78	23.70	19.65	1.86	2.64	2.20
Associated with falling	4	---‡	4	6.71	---	3.93	0.75	---	0.44
Other	---	1	1	---	2.37	0.98	---	0.26	0.11
Total	**71**	**38**	**110**	**119.13**	**90.06**	**108.1**	**13.39**	**10.03**	**12.1**

* M: Males; F: Females.
†: Gender was not indicated.
‡: Injuries were not occurred
Note: One missing case in this table.

Table 2-6. Distribution of 99 WTCs injuries by the technique

Technique	Frequency			Injury rate per 1,000 A-E			Injury rate per 1,000 M-E		
	M*	F*	Total	M	F	Total	M	F	Total
Front snap kick	8	3	11	13.42	7.11	10.81	1.51	0.79	1.21
Roundhouse kick	35	25	61†	58.72	59.24	59.92	6.60	6.60	6.71
Side kick	8	1	9	13.42	2.37	8.84	1.51	0.26	0.99
Back kick	1	1	2	1.68	2.37	1.96	0.19	0.26	0.22
Axe/hook kick	2	1	3	3.36	2.37	2.95	0.38	0.26	0.33
Spinning kick	4	---‡	4	6.71	---	3.93	0.75	---	0.44
Cutting kick	1	2	3	1.68	4.74	2.95	0.19	0.53	0.33
Other	10	5	15	16.78	11.85	14.73	1.89	1.32	1.65
Total	**69**	**38**	**108**	**115.77**	**90.05**	**106.09**	**13.02**	**10.02**	**11.88**

* M: Males; F: Females.
†: Gender was not indicated.
‡: Injuries were not occurred
Note: Three missing cases in this Table. Publisher made typo errors in this table. The highlighted values here are the actual values found in this study.

Table 2-7. Distribution of 99 WTCs injuries by weight division

Weight division	Frequency			Injury rate per 1,000 A-E			Injury rate per 1,000 M-E		
	M*	F*	Total	M	F	Total	M	F	Total
Fin	12	6	18	20.13	14.22	17.68	2.26	1.58	1.98
Fly	4	3	7	6.71	7.11	6.88	0.75	0.79	0.77
Bantam	10	5	15	16.78	11.85	14.73	1.89	1.32	1.65
Feather	5	4	9	8.39	9.48	8.84	0.94	1.06	0.99
Light	10	8	18	16.78	18.96	17.68	1.89	2.11	1.98
Welter	15	2	17	25.17	4.74	16.70	2.83	0.53	1.87
Middle	6	6	13†	10.07	14.22	12.77	1.13	1.58	1.43
Heavy	9	4	13	15.10	9.48	12.77	1.70	1.06	1.43
Total	**71**	**38**	**110**	**119.13**	**90.06**	**108.05**	**13.39**	**10.03**	**12.1**

* M: Males; F: Females.
†: Gender was not indicated.
Note: One missing case in this Table.

Table 2-8. Distribution of 99 WTCs injuries by severity

Severity	Frequency			Injury rate per 1,000 A-E			Injury rate per 1,000 M-E		
	M*	F*	Total	M	F	Total	M	F	Total
Mild	36	20	57†	60.40	47.39	55.99	6.79	5.28	6.27
Moderate	15	12	27	25.17	28.44	26.52	2.83	3.17	2.97
Severe	20	6	26	33.56	14.22	25.54	3.77	1.58	2.86
Total	71	38	110	119.13	90.05	108.05	13.40	10.03	12.1

* M: Males; F: Females.
†: Gender was not indicated.
Note: One missing case in this Table.

CHAPTER 3

Video Analysis Blows to the Head and Face at the 1999 World Taekwondo Championships[1]

INTRODUCTION

Competition Taekwondo or Olympic Taekwondo is a free-sparring full contact sport in which high scores or knock-outs (KO) determine the winner of a match. Points are scored when a kick or a punch made to a legal scoring area (i.e., torso and face) is powerful enough to generate a so-called "trembling shock"[2]. In general, most points are scored by kicking techniques (approximately 80 to 90 %) rather than punching techniques in competition Taekwondo. For these kicks to be scored, they must produce sufficient force to result in an observable movement of the target zone. As a result, kicking techniques pose potential injuries to the competing athletes.

Two studies on the thoracic injury potential of basic Taekwondo kicks have been published (Serina & Lieu, 1991; Chuanng & Lieu, 1992). Serina and Lieu's (1991) study measured velocities of four basic competition Taekwondo kicks (e.g., roundhouse kick = 15 ms^{-1}), and calculated the energy produced (roundhouse kick = 200 J). They found that the roundhouse and turning-roundhouse kicks are faster and have a greater potential for soft tissue injury. Also, the back and side kicks can generate large chest compressions and thus may have more potential for skeletal injury when contact is made with the body of the opponent. In particular, blows to the head region occur commonly in Taekwondo

[1] A version of this chapter has been published. Koh & Watkinson, 2002. The Journal of Sports Medicine & Physical Fitness. Volume 3.
[2] Trembling shock is demonstrated as the opponent's body is abruptly displaced by the impact of the strike.

competitions since the face is a major scoring region. Chuang and Lieu's (1992) study confirmed many of these findings.

Other studies have reported types of injury to the head and face: contusion, laceration, facial fracture, dislocation and concussion (Koh, De Freitas, & Watkinson, 2001; Pieter & Zemper, 1999, 1998; Pieter & Lufting, 1994; Siana, Borum, & Kryger, 1986). Among these injuries, there are growing concerns with respect to concussion due to its potentially detrimental effects. The frequency of head concussion seems to have increased during World Taekwondo Championships, from one reported concussion in 1983 (Siana, Borum, & Kryger, 1986), to nine and eight concussions in 1991 (Pieter & Lufting, 1994) and 1999 (Koh, De Freitas, & Watkinson, 2001), respectively. During this period, the mandatory usage of headgear was established (in 1985). Generally, the purposes of using protective equipment such as headgear are not only to absorb energy upon impact but also to distribute the impact over the skull and over a longer period of time (Lloyd, Lauderdale, & Betz, 1987). According to most injury reports, however, wearing headgear in Taekwondo competition reduced the frequency of injuries such as facial bone fractures, but not head concussion. Thus, head blows may predispose an athlete to potential brain injury regardless of wearing protective headgear.

Several studies on competition Taekwondo injuries have been published. However, no research has been done on head blows, particularly those that may result in mild traumatic brain injury in competition Taekwondo. Therefore, the purpose of this study was to investigate the fighting conditions under which blows to the head commonly take place, with a view to determining the typical conditions under which injury may occur. Specifically, by examining videotapes of world class competition and describing head blow situations that could lead to mild traumatic brain injury, the authors analyzed the mechanisms and exact kicking techniques involved. Furthermore, the event leading up to, and following, each significant head blow in these bouts was examined, leading to recommendations and considerations for training and competing in Taekwondo.

METHODS

Head blows were ascertained by inclusion and exclusion criteria from the semi-final and final matches at the 14th World Taekwondo Championships on June 2-6, 1999 in Edmonton, Canada. A total of 64 athletes (32 females and 32 males) who won elimination-round matches competed in the semi-final and final matches. All but the first round of the semi-final matches, and all of the final matches were videotaped by a commercial company (Champions 2000 Martial video company, CA, USA). These videotapes were studied such that every head blow event was identified and scrutinized in detail. In total, 48 matches were analyzed.

Videotapes were analyzed using a form that described gender, weight division, and time of head impact. Head blow events were included in the full analysis if one of the following criteria were met:

1) The head moved rapidly following impact.
2) The athlete demonstrated a stunned or dazed state for any period following impact.
3) The referee called standing down (usually 8-count).
4) The attacker was awarded a point.
5) The receiver demonstrated gait unsteadiness (an ataxic, stumbling, off-balance, or unsteady gait with a tendency to fall).

6) An athlete received a blow to any body region and then his or her head region contacted the playing surface as a result of falling.
7) There was apparent loss of consciousness lasting seconds to minutes.

Head blow events were excluded from the analysis when one of the following occurred:

1) No head movement followed a head blow due to insufficient power from the kick or punch or insufficient contact to the head region (i.e., when the blow was not scored).
2) When the impact and immediate post-impact period were obscured.

The tapes were coded so that the movements of both combatants were included, and a full description of events leading up to and following head impact could be characterized. A coding sheet that included all of the potential situations/mechanisms and techniques for both fighters was produced (see Figure 3-1). Thirty-five head blow events met the inclusion criteria. These events were then coded. Height difference, kicking technique, fighting type, attempted evasive maneuvers (i.e., blocking skills or other), anatomic impact site, the presence of a double or multiple impact, head movement post-impact, and any changes in stance or gait post-impact were each identified. A second and third observer coded 15 % of the head blow events. Inter-observer agreement [(number of agreements/number of agreements + disagreements) x 100 %] was calculated at > 97 %. The only coding disagreement was on height difference where observers coded the athlete as taller, shorter, or of similar stature. Tapes were reviewed in both slow motion and normal speed as many times as required by each observer to feel confident in coding decisions.

RESULTS

Based on the inclusion and exclusion criteria, a total of 19 cases (9 females and 10 males), some involving more than one head blow, were analyzed from the semi-final and final matches at the 1999 World Taekwondo Championships. The overall head blow incidence was 365 head blows per 1,000 athlete exposures (athlete exposure refers to an athlete being exposed to the possibility of sustaining an injury).

Twelve cases (63%) of potential injury occurred during semi-final matches (a total of 64 athletes, 32 matches, 96 rounds, and 288 minutes) and seven cases (37%) of potential injury occurred during final matches (a total of 16 matches, 48 rounds, and 144 minutes).

Table 3-1 shows the frequency of cases by weight class. Table 3-2 shows frequency of total head blows by observed features addressed in the inclusion criteria. All head blows involved direct contact to either the face/jaw or back/side of the head. Also, head displacement was detected immediately post-impact for each blow. In ten cases (53%) out of 19, two or more head blows were sustained during semi-final and final matches.

Table 3-3 shows frequency of total head blows by technique. Characteristics of situations leading to the head blows and described by actions of attacker/receiver and by sparring stance (position) are listed in Table 3-4 and Table 3-5. The mechanism of all head blow cases was the reception of a direct kick to the head region. Overall, the distribution of the attacker's kicking types were a single kick (86%), followed by a double kick (7%), and a combination kick (6%).

Among competitors who received a head blow during their matches, nine (47%) were shorter then their opponent, five (26%) were taller than their opponent, and five (26%) were of similar height. Immediately before the head blow, the match was led more often by the attacker (60%) than the receiver (34%). One case (6%) of a tied score was observed. Sixty-three percent (22) of the blows were made by the left foot and 37% (13 blows) by the right foot. Fifty-seven percent of these blows were made (20 blows) by the front or leading foot and 43% (15 blows) by the back foot. Kicking techniques that caused a second head blow (ten cases out of 19) were dominated by the axe kick (70%), followed by the roundhouse kick (20%), and back kick (10%) (see Table 3-6). None of the 19 receivers attempted evasive maneuvers (i.e., no blocking skill was utilized) in response to the attacker. Among the recipients of a head blow, seven athletes won the match and 12 athletes lost the match.

DISCUSSION

When the incidence of head blow takes into account only the total number of semi-final and final participants (64 athletes), the rate of incidence is very high in terms of athlete or minute- exposures (19/96 x 100 = 19.7 cases per 100 athlete-exposures and 20 [12 – 28%] cases per 100 athlete-exposures at 95% CI). Furthermore, among a total of 19 incidents of a head blow, eight athletes received a double head blow and two athletes received multiple head blows during semi-final and final matches at the 1999 World Taekwondo Championships. Such a double or multiple head blow requires caution in terms of prevention of possible serious injury and long-term detrimental effects, even when symptoms are not apparent and the athlete's performance is not hindered immediately. According to Barth et al. (1989), an important factor contributing to long-term deficits is the cumulative effect of multiple blows to the head, and not necessarily those resulting in knockouts. Studies on effects of multiple head blows in other contact sports have been conducted. Barnes et al. (1998) found that over half of the Olympic soccer players studied experienced at least one headache after heading. These findings indicated that repeated direct blows or subconcussive blows to the head were a plausible cause. Master, Kessels, Lezak, Troost, and Jordan (2000) have found that amateur boxers who received at least eight punches to the head during competition, of which 13% brought about a concussive state (i.e., a knockout or technical knockout), showed diminished neurocognitive functions such as planning, attention, and memory capacity when compared with controls (boxers who did not compete) despite the use of headgear.

The most dominant kicks that caused a head blow were the axe kick (18 blows, 51 %), followed by the roundhouse kick including turning-roundhouse kick (11 blows, approximately 31%), spinning kick, and back kick. Pieter, van Ryssegem, Lufting, and Heijmans (1995) have reported that both the roundhouse and spinning kick were the cause of sustained concussion in both genders. In the present videotape observations, the cases that involved falling (being knocked down) or gait or posture unsteadiness (including body sway, and balance recovery) were caused predominantly by the roundhouse kick, followed by the spinning kick, and the axe kick. Due to the fact that all types of Taekwondo kicking techniques embody high speed and power, these kicks have a potential for injury. According to Serina and Lieu (1991) the roundhouse and turning-roundhouse kicks (approximately 15.9 ms^{-1}) possess greater foot velocities than the side kick and back kicks (8.8 ms^{-1}). In addition, Sung, Lee, Park, and Joo (1987) have measured velocity on impact of the roundhouse kick at 19.2 ms^{-1}. The 1986 Korean national Taekwondo team members were employed in those investigations.

Table 3-4 shows the situation leading up to head blows. The results show that 13 athletes (37%) received a head blow while they were engaged in an offensive action. Such a situation may potentially render more serious injury because the resultant blow is the additive force of the attacker's kick as well as the receiver's forward momentum.

Approximately 66% of head blows were received in a closed stance position and 31% received in open stance position (Table 3-5). One possible reason for this is that the closed stance position allows minimum visualization for torso target areas but not for the face or head region. Put differently, in this stance, the torso is protected from the opponent, leaving the head or face as the primary target for kicks.

Among all the present head blows, none involved attempting or preparing evasive maneuvers at the time of head trauma. One possible reason for this phenomenon is that the athlete was preoccupied by offensive movements, and was not concentrating on preventing the opponent from getting points. Also, the athlete may not have anticipated the head blow. Furthermore, athletes may have greater training in kicking skills than blocking skills. To avoid or reduce head blows, utilization of blocking skills may be helpful. Perhaps athletes should practice blocking in concert with the offensive movement. Moreover, coaches and athletes should develop various training programs, which include placing more emphasis on Taekwondo blocking skills (e.g., training with one arm raised over the shoulder while training offensive or defensive actions) and adapting the strategies to avoid head blows that are typically used in other sports (e.g., ducking in boxing).

There has been a lack of concern over athletes who have sustained repeated head blows or concussions with no loss of consciousness or instantly apparent symptoms or signs. Although obvious features of mild traumatic head injury such as loss of consciousness, confusion, disorientation, stunned or dazed state, and gait unsteadiness post-trauma were not detected for all cases presented here, a direct blow to the head is caution enough as it may potentially result in brain injury. Furthermore, a recent study (Delaney, Lacroix, Leclerc, & Johnston, 2000) has indicated that many incidents of concussion are not detected by the athletes. The study found that 44.8% of 154 football players experienced concussion symptoms during the 1997 Canadian Football League season. Less than a half (18.8%) of these concussed athletes identified that they had sustained a concussion. Further research is needed to explore the experience of a direct head blow and the short-term and long-term effects that follow such a blow in Taekwondo. In order to prevent or reduce serious injury, rule changes in competition Taekwondo could be considered. For instance, if further research indicates that repeated concussions can lead to more than temporary injury, an athlete who has received a direct head blow more than two times at the same tournament could be ineligible to continue the rest of the fight. As well, updated safety education, especially with respect to concussion in competition Taekwondo, could be required for athletes, coaches, and referees.

In summary, a total of 35 incidents of head blow occurred at the semi-final and final matches of the 1999 World Taekwondo Championships. All of these head blows were associated with a direct head or face contact and frequently involved: a closed sparring position, shorter athletes, axe or roundhouse type kicks, attacker's offensive kick, and head blow receiver's offensive action with absence of a blocking skill.

CONCLUSIONS

In conclusion, to prevent possible brain injury from a direct head blow with no loss of consciousness, updated safety education, including a complete understanding of concussion for athletes, coaches, and referees, and rule changes in competition Taekwondo are recommended. In addition, more research on frequency of head blows, the experience of a direct head blow, and the effects that follow such a blow in Taekwondo is necessary.

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Table 3-1. Frequency of head blows by weight class

Weight class	Male	Female	Total frequency	Percent of total head blow cases
Fin	2	1	3	15.8
Fly	1	0	1	5.3
Bantam	0	0	0	0
Feather	1	2	3	15.8
Light	1	1	2	10.5
Welter	3	3	6	31.6
Middle	2	1	3	15.8
Heavy	0	1	1	5.3
Total	**10**	**9**	**19**	**100.0**

Table 3-2. Frequency of head blows by observed features

Observed feature	Frequency of total head blows
Direct contact of the head region	35
Head displacement post-impact	35
Fall post-impact	3
Gait unsteadiness (including off balance post-impact)	4
Loss of consciousness (knocked-out)	0
Knocked-down	3
Stunned or dazed	4
Single head blow	9 (Cases)
Double head blows	8 (Cases)
Multiple head blows	2 (Cases)

Table 3-3. Frequency of total head blows by techniques

Technique	Male	Female	Total frequency	Percent of total head blow events
Axe kick	7	11	18	51.4
Roundhouse kick	4	5	9	25.7
Turning-Roundhouse kick	1	1	2	5.7
Spinning (360 degree) kick	2	2	4	11.4
Back kick	1	1	2	5.7
Total	**15**	**20**	**35**	**100.0**

Table 3-4. Leading situation of head blow by attacker and receiver actions

Situation and Mechanism	Male	Female	Total	Percent of total head blow events
Attacker's offensive action	11	11	22	62.9
Attacker's defensive action (counter-attack)	4	9	13	37.1
Total	**15**	**20**	**35**	**100.0**
Receiver's offensive action	4	9	13	37.1
Receiver's defensive action	1	3	4	11.4
No Receiver's action	10	8	18	51.4
Total	**15**	**20**	**35**	**100.0**

Table 3-5. Leading head blows by sparring stance (position)

Sparring stance	Male	Female	Total frequency	Percent of total head blow events
Closed stance*	11	12	23	65.7
Open stance†	4	7	11	31.4
Other	0	1	1	2.9
Total	**15**	**20**	**35**	**100.0**

* Closed stance: Two athletes are standing with the same side of foot in front (e.g., left foot in front and right foot in back).

† Open stance: Opposite to the Closed stance (e.g., one of the athlete's left foot is in front and right foot in back, and the other athlete's right foot is in front and left foot in back).

Table 3-6. Second head blow case by technique

Techniques	Male	Female	Total frequency	Percent of total second head blow cases
Axe kick	3	4	7	70.0
Roundhouse kick	0	2	2	20.0
Back kick	1	0	1	10.0
Total	**4**	**6**	**10**	**100.0**

Category	Indicator
Height difference	Taller / Shorter / About same
Technique	Axe / Roundhouse / Turning-roundhouse / Spinning / Back / Side kick
Head blow situation	
a. Attacker's fighting type	Offensive / Defensive
b. Attacker's kicking type	Single / Double / Combination kick type
c. Attacker's dominant side of leg	Left / Right
d. Receiver's fighting type	Offensive / Defensive
e. Receiver's kicking type	Single / Double / Combination kick type
f. Blocking skill	Used / Not used
g. Sparring stance (position)	Closed / Open stance
h. Which side of the foot in front	Attacker: Left / Right foot Receiver: Left / Right foot
Head displacement	Yes / No Displacement direction:__________
Anatomical site of impact	Side or back of the head / Face / Jaw
Problems post impact	Balance (including fall, off-stance etc.) Gait problem No change
Presence of multiple blows	1 / 2 / 3 / 4 / 5 / 6 / 7 time head blow (s)

Figure 3-1. Coding scheme for videotape analysis of head blows

CHAPTER 4

Incidence of concussion in contact sports: A systematic review of the evidence[1]

INTRODUCTION

Concussion is a common type of head injury that can occur in most contact sports. It is defined as traumatically induced physiological disruption of brain function with a short period of altered or loss of consciousness (The Mild Traumatic Brain Injury Committee of the Head Injury Interdisciplinary Special Interest Group of the American Congress of Rehabilitation Medicine, 1993). Past literature indicates that the incidence of concussion in contact or collision sports is higher than in noncontact sports. Although the consequences of a concussion are controversial, there is concern about cumulative effects and the high risk of developing long-term behavioral or cognitive problems from multiple concussions. In addition, several studies suggest that athletes who have had a prior concussion have a higher risk of repeated concussions. Such considerations can have a significant impact on the continuance of an athletic career, causing temporary suspension of play and even early retirement in some cases.

In general, injury incidence studies have become useful tools to estimate risk, to identify risk factors, and to guide injury prevention. Narrative reviews have also provided broad information on this topic. However, narrative reviews do not have explicit methods and are therefore prone to bias. For example, narrative reviews have no explicit search strategy or method of quality appraisal of articles. On the other hand, a systematic review should be reproducible and have explicit criteria for appraising evidence from articles

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[1] A version of this chapter has been submitted to Brain Injury for publication (May 2002).

(Cook, Greengold, Ellrodt, & Weingarten, 1997; Cook, Murlrow, & Haynes, 1997). A systematic review could be thought of as an experiment where the unit of analysis is a research paper. These issues of methodology are important when the results of reviews are used to direct athletes' care, or to assist the leisure planner and parent in decision-making for the choice of sports, or to provide the coach, governing body, manufacturer, or medical personnel with the best scientific evidence to promote injury prevention. Moreover, a good systematic review will link conclusions to evidence tables that summarize evidence from accepted articles.

The purpose of this systematic review is to estimate the incidence of concussion in contact sports.

METHODS

Our method for this systematic review is based on guidelines for systematic review published by the Evidence-Based Medicine Working Group (Cook et al., 1997; Cook et al., 1997; Counsell, 1997; Meade & Richardson, 1997) and methods developed from past experience (Spitzer, Skovron, Salmi, & Cassidy, 1995; Côté, Cassidy, Carroll, Frank, & Bombardier, 2001).

For our systematic review, concussion was defined as a mild brain injury resulting from a direct blow (blunt trauma) to the head resulting in physiological changes in brain function. A concussed athlete may experience at least one of the following: any period of loss of consciousness (30 minutes or less); any loss of memory for events immediately before or after the injury (posttraumatic amnesia not greater than 24 hours); any alteration in mental state at the time of the event (e.g., feeling dazed, disoriented, or confused);

focal neurological deficit(s) that may or may not be transient; an initial Glascow Coma Scale (GCS) of 13-15. There should be no evidence of skull fracture or intracranial pathology.

Our systematic review is focused on cohort studies that documented the incidence (i.e., cumulative incidence and incidence density) of a concussion as a result of the following contact sports: American football, boxing, ice hockey, martial arts (judo, karate, and taekwondo), rugby, and soccer. Boxing and the martial arts were selected because forceful contact between opposing players in these sports is required for earning points. Football and rugby were selected because body contact between opposing players occurs routinely during each play. Ice hockey and soccer were included because of special circumstances in each game that may predispose players to injury. In ice hockey, athletes are at risk of concussion because of the speed at which body contact occurs and the surfaces (ice and boards) which opposing players are checked against. Heading the ball in soccer may place the athletes at risk of concussion.

Our systematic review includes all male and female athletes of all ages who took part in one of the eight sport activities, including practice or training and game or competition, regardless of competitive levels.

Literature search and selection of articles

The goal of the search strategy was to be as comprehensive as possible. The first step was to create core concepts (i.e., brain, concussion and sports) using review articles. The second step was to subdivide those concepts into head, injury, football, boxing, hockey, and other sports. The third step was to search Medline (1985-2000) using OVID

SOFTWARE. This search was based on specific key words (head injury, brain injury, brain concussion, mild traumatic brain injury, our eight sports, and incidence) and the text words (concussion, incidence, injury, head injury, and our eight sports). All search terms were limited to the English language, studies of humans, and the years 1985 to 2000. We chose the period 1985-2000 to focus on current information, but we also reviewed older papers cited in this literature.

We used a three-step screening strategy to identify the articles to be reviewed. First, the titles were screened by one of the authors. An examination of randomly selected articles that were excluded by title revealed that theses articles addressed sports or injuries that were irrelevant to our purpose. Second, the abstracts were subsequently screened for the inclusion and exclusion criteria to identify relevant articles. The inclusion criteria were as follows:

1) Studies of the incidence of injury to the head or brain.
2) Article reports results relevant to concussion, mild traumatic brain injury, or diagnostic criteria that are used for concussion. Also included were other terms such as mild brain injury, minor head injury and mild closed head injury.
3) Eight contact sports (football, boxing, ice hockey, martial arts [judo, karate, taekwondo], rugby and soccer) were included.
4) All systematic review articles about mild traumatic brain injury or concussion were included.
5) Articles published from 1985 to 2000.

The exclusion criteria were as follows:

1) Concussion is due to whiplash injury (no evidence of direct trauma or blunt trauma to the head).
2) Spinal cord injury, facial bone fracture and soft tissue injuries.
3) Article reports prevalent, rather than incident, cases of concussion.
4) Absence of a denominator (athletes at risk or time at risk).
5) Studies of chronic traumatic brain injury.
6) Single case reports or letters to the editor.

In a third step of screening, relevant and unknown articles from the abstract screening were reviewed independently for the inclusion/exclusion criteria. Once again, a sample of the excluded articles revealed that they were irrelevant to our purpose.

Assessment of methodological quality, data abstraction and synthesis of results

All articles which met the inclusion/exclusion criteria were critically appraised using general methodological criteria (Table 4-1) for appraising the quality of cohort studies (Côté et al., 2001). These criteria were selected to assess the presence of common biases. To be accepted, an article had to meet five of the eleven criteria, including: 1) the source population had to be described; 2) the inclusion/exclusion criteria had to be described and appropriate; 3) the results had to be verifiable from the raw data; 4) the injury occurrence had to be differentiated into practice or game time; and 5) the denominator (population at risk or person-time at risk) had to be adequately measured. Each condition was rated as yes, no, or substandard. If any of the above five mandatory criteria were rated as no, the article was rejected as scientifically inadmissible.

In some papers, the incidence rate was re-calculated using the number of concussed athletes as a numerator and the population at risk or person-time at risk as a denominator. Also, we calculated 95% confidence intervals around the incidence estimates.

RESULTS

The results from the literature search and selection of articles are summarized in Figure 4-1. Overall, our search found 559 publications. A title screening of these left 213 abstracts to review. These abstracts were screened for relevance giving 62 relevant abstracts and 65 abstracts where the relevance could not be determined. We applied our inclusion/exclusion criteria to the full text of these 127 articles. Of those, several papers were excluded since the study subjects or results were duplicated in another paper. Overall, fifty-seven articles were identified as relevant for mild traumatic brain injury (concussion) in eight contact sports. In addition, six other papers were found by searching reference lists. Therefore, 63 articles were subjected to critical review by the investigators. No study or systematic/narrative review of concussion in judo was identified.

Of the 63 reviewed articles, 40 were excluded because they were below the methodological quality cut-point (Albright, Mcauley, Martine, Crowley, & Foster, 1985; Bird et al., 1998; Critchley, Mannion, & Meredith, 1999; Cunningham & Cunningham, 1996; DeLee & Farney, 1992; Gabbett, 2000; Gissane, Jennings, & Standing, 1993; Hillman, Dicker, & Sali, 1993; Juma, 1998; Kibler, 1993; McMahon, Nolan, Bennett, & Carlin, 1993; Nilsson & Roaas, 1978; Norton & Wilson, 1995; Pettersson & Lorentzon, 1993; Putukian, Knowles, Swere, & Castle, 1996; Schmidt-Olsen, Bünemann, Lade, & Brassøe, 1985; Schmidt-Olsen, Jensen, & Mortensen, 1990; Seward, Orchard, Hazard, & Collinson, 1993; Tegner & Lorentzon, 1991; Shawdon & Brukner, 1994; Zemper, 1994; Barnes et al., 1998; LaPrade, Burnett, Zarzour, & Moss, 1995; Lorentzon, Wenrèn, & Pietilä, 1988; Gerberich et al., 1987; Benson, Mohtadi, Rose, & Meeuwisse, 1999; Mölsa, Airaksinen, Nasman, & Torstila, 1997; Dryden, Francescutti, Rowe, Spence, & Voaklander, 2000; Carson, Roberts, & White, 1999; Sparks, 1985; Havkins, 1986; Schmidt-Olsen, Jørgensen, Kaalund, & Sørensen, 1991; Boden, Kirkendall, & Garrett, 1998; Garraway & Macleod, 1995; Lee & Garraway, 2000; Gissane, Jennings, Cumine, Stepheson, & White, 1997; Buckley, 1986; Meeuwisse, Hagel, Mohtadi, Butterwick, & Fick, 2000; Wilson, Quarrie, Milburn, & Chalmers, 1999; Guskiewicz, Weaver, Padua, Garrett, 2000). Most of these papers did not report gender, give a denominator (i.e. athlete or time at risk of injury), report raw data, or differentiate risk sessions (either games or practices). Also, three papers were excluded because they were duplicated articles (Lee & Garraway, 2000; Gissane et al., 1997; Buckley, 1986). Two studies on concussion of 395 college football teams reported inconsistent numerators (i.e. numbers of concussions in games) and denominators (i.e. numbers of subjects at risk), although the frequency of total concussion from these two papers was identical (Buckley, 1986; Buckley, 1988).

In many studies of team sports, time at risk for concussion was not measured accurately, which limits our ability to determine risk. Few studies reported both "persons at risk of injury" and "time at risk of injury" (Pieter & Zemper, 1998; 1999; Powell & Barber-Foss, 1999; Koh, De Freitas, & Watkinson, 2001). Also, a number of studies did not differentiate whether concussions occurred during training or game time (Zemper, 1994; Barnes et al., 1998; LaPrade et al., 1995; Lorentzon et al., 1988; Gerberich et al., 1987; Benson et al., 1999; Mölsa et al., 1997; Dryden et al., 2000; Carson et al., 1999; Sparks, 1985; Havkins, 1986; Schmidt-Olsen et al., 1991; Meeuwisse et al., 2000; Guskiewicz et al., 2000). This limitation hinders precise evaluation of the risk of concussion due to the different risks existing in practice and competition. Moreover, most studies used a definition of injury or reportable injury, but only 14 studies (Zemper, 1994; Sparks, 1985; Boden et al., 1998; Guskiewicz et al., 2000; Buckley, 1988; Pieter & Zemper, 1998; Powell & Barber-Foss, 1999; Koh et al., 2001; Stephenson, Gissane, & Jennings, 1996; Jordan & Campbell, 1988; Myers, 1980; Pelletier, Montelpare, & Stark 1993; Pieter & Lufting, 1994; Porter & O'Brien, 1996) used an explicit definition of concussion. Furthermore, incidence rate computations in some studies were calculated inaccurately or questionably (Lee & Garraway, 2000; Gissane, Jennings, White, & Cumine, 1998; Tegner & Lorentzon, 1996). Thirteen studies did not report the total number of participants (LaPrade et al., 1995; Mölsa et al., 1997; Gissane et al., 1997; Powell & Barber-Foss, 1999; Stephenson et al., 1996; Myers, 1980; Pelletier et al., 1993; Porter & O'Brien, 1996; Gissane et al., 1998; Tegner & Lorentzon, 1996; Gibbs, 1993; Lindenfeld, Schmitt, Hendy, Mangine, & Noyes, 1994; Sparks, 1981). In addition, only four out of 63 papers reported previous history of concussion (Albright et al., 1985; DeLee & Farney, 1992; Zemper, 1994; Gerberich et al., 1987). Finally, four studies did not specify the year of investigation (LaPrade et al., 1995; Schmidt-Olsen et al., 1991; Lindenfeld et al., 1994; Jørgensen & Schmidt-Olsen, 1986). Only one study included an a-priori sample size calculation to ensure an adequate sample to present a stable risk estimate (Benson et al., 1999).

Taking into account the limitations discussed, information from the 23 accepted articles is presented in Tables 4-2 to 4-8 including the incidence rates. For some studies, we recalculated the rates from the raw data. This was done to check the accuracy of published rates, or to calculate rates when they were not presented. These tables are based on the studies that have clearly specified gender, sessions (either games or practices), and a re-calculable denominator. Only twenty-three (Buckley, 1988; Pieter & Zemper, 1998, 1999; Powell & Barber-Foss, 1999; Koh et al., 2001; Stephenson et al., 1996; Jordan & Campbell, 1988; Myers, 1980; Pelletier et al., 1993; Pieter & Lufting, 1994; Porter & O'Brien, 1996; Gissane et al., 1998; Tegner & Lorentzon, 1996; Gibbs, 1993; Lindenfeld et al., 1994; Sparks, 1981; Jørgensen & Schmidt-Olsen, 1986; Dicker, 1986; Pieter, van Ryssegem, Lufting, & Heijmans, 1995; Roberts, Brust, & Leonard, 1999; Roberts, Brust, Leonard, & Hebert, 1996; Stricevic, Patel, Okazaki, & Swain, 1983; Welch, Sitler, & Kroeten, 1986) out of 63 relevant papers could be used to estimate the risk of concussion in our selected sports.

Overall, ice hockey shows the highest incidence of concussion amongst the team sports (American football, ice hockey, rugby, and soccer) for high school male athletes. However, ice hockey and rugby have similar rates at the professional level. Soccer has the lowest frequency of concussion among the four team sports in high school male athletes. Not surprisingly, boxing shows the highest frequency of concussion in terms of time at risk among the three individual sports (boxing, karate, and taekwondo) at the recreational and competitive level in males.

There are few studies of concussion in contact sports involving females. Of those, taekwondo shows the highest incidence of concussion, regardless of age.

DISCUSSION

A full discussion of the incidence of concussion in team sports must acknowledge that the rules, techniques, and strategies of a particular game may significantly predispose athletes to concussion. Football linemen, for example, frequently use their heads and shoulders to contact the opponent with considerable force, while this is illegal in soccer. However, shoulder contact can be made by the opponent against a soccer player who has possession of the ball. In the case of soccer, head contact occurs when heading the ball. Furthermore, significant differences in player roles may predispose some player positions to concussion and not others, and specific local, national or international rules regarding contact may influence the incidence of concussion in different age groups (e.g. Masters level ice hockey) and in women (e.g. in ice hockey). Overall, one would expect to see an increased incidence of concussion in sports involving frequent forceful contact such as hockey, football, taekwondo and boxing, and lower rates in sports, such as soccer where contact between players is less frequent.

Overall, ice hockey shows the highest incidence of concussion among the four team sports for high school, college and amateur adult males. Although ice hockey and American football players wear full equipment compared with rugby and soccer players, the incidence of concussion in the former sports is higher. One possible reason for this phenomenon is over-reliance on protective equipment. Athletes who use full protective equipment may believe they are protected from injurious forces, and may tend to be more aggressive and violent. Furthermore, protective equipment, especially helmets, may not be properly placed or secured, and may not be of suitable size or quality. For safety reasons, these issues should not be ignored by athletes, coaches, and sport governing bodies.

Boxing shows the highest frequency of concussion among the three individual sports. Interpretation of these results requires caution due to information biases. For example, the definition of concussion used in each study may not be the same. In boxing, a knockout or any technical knockout is often used as a definition of concussion. However, all technical knockouts do not always result in concussion (Jordan & Campbell, 1988). Therefore, the incidence of concussion in boxing might be overestimated. On the other hand, in other sports, including team sports, the incidence of concussion may be underreported or underestimated due to a lack of concern when no apparent loss of consciousness is present. In order to compare the risk of concussion across sports, a valid and uniform definition of concussion is required.

Our literature search yielded no studies on judo, which involves much physical contact during matches and training. We need more research on concussion in this sport. There are also insufficient studies of injury in contact sports involving females. Of these, taekwondo shows the most frequent occurrence of concussion, regardless of age. This may be due to the large number of female participants in taekwondo, and to the nature of competition taekwondo, which promotes attacking the face and head using kicking techniques. The governing bodies of this sport might need to reconsider the safety of this approach.

In this review, only twenty-three articles could be used to estimate risk of concussion in the sports under study. In other words, only 37% out of all relevant research papers (63 papers) were useful to measure risk of concussion in our review.

We identified several general methodological problems in the studies we reviewed. First, the source population was not always clearly identified, including characteristics such as gender, age, country, and the year of the data collection. Second, the inclusion and exclusion criteria for many studies were not reported. Third, raw data were not always reported, such as exposure data and the frequency of injury. Fourth, only one study reported a pre-planned sample size, which helps to plan better precision around incidence estimates (Benson et al., 1999).

We found other limitations in the studies we reviewed. Some studies failed to identify whether injuries occurred during game or practice, or the level of competition of the sport under study. Reported concussion rates were often combined from game and practice sessions. Also, only four studies reported on previous history of concussion. This issue is very significant in terms of adequate measurement of exposures, since the risk of concussion may be higher for someone who has had a concussion in the past. (Albright et al., 1985; DeLee & Farney, 1992; Zemper, 1994; Gerberich et al., 1987). In addition, the denominator, time or person at risk data, was roughly measured in many team sports. Also, substitute players were not always included in the calculation of both persons at risk of injury and time at risk of injury. In some cases, calculations of results were incorrect or difficult to reproduce. Finally, many studies did not have an explicit definition of concussion. Future studies on the incidence of concussion should address these issues.

The findings from the present systematic review are significant in terms of identifying the incidence of concussion in eight different sports. These rates may be useful guides for future studies of prevention. However, we found few good studies on the incidence of concussion in contact sports, and a lack of research on concussion for females in contact sports and judo. Furthermore, there are some significant methodological limitations in this literature and considerable scope for improvement for future studies.

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Table 4-1. Criteria for the assessment of the methodological quality

General methodological criteria
1. Research question is clearly stated
2. Source population is described*
3. Inclusion/exclusion criteria are described and appropriate*
4. Number of subject exclusion or refusals (before study) is reported
5. Sample size is pre-planned and provided adequate statistical power
6. Statistical analysis is appropriate
7. The results are verifiable from the raw data*
8. The injury incidence is clearly differentiated into practice or game settings*
9. Important variables are measured (e.g., gender and age) is defined at entry into study
10. Numerator (concussion) is defined
11. Denominator (population or person-time at risk) is adequately measured*

* Mandatory criteria for acceptance of article.

Table 4-2. Summary of study characteristics of risk of concussion in American football

Study period	Source population	Denominator	Injury definition & number of concussion	Author's incidence [1st author of the study]	Recalculated incidence & 95% confidence intervals (CI)*
1975-1982	395 United States college teams (males)	3,012,063 AE† in practices and 216,691 AE in games	Immediate impairment of neural function including all signs, symptoms, and sequelae. Overall 2,124 concussions; 725 game-related concussions.	6.6/10,000AE in games and practices [Buckley, 1988].	3.35 (95% CI, 3.10-3.59)/1,000 AE in games and 0.46 (95% CI, 0.44-0.48)/1,000 AE in practices.
1995-1997	235 United States high schools (males)	21,122 player-seasons	Cessation of participation for initial observation and evaluation before returning to play. Total of 773 concussions.	0.25 (95% CI, 0.16-0.34) /1,000 practice exposures and 2.82 (95% CI, 2.58-3.07) /1,000 game exposures [Powell, 1999].	

*: Incidence was recalculated in some cases. We also calculated 95% CI's if not presented in an original paper.

† AE: Athlete Exposures.

Table 4-3. Summary of study characteristics of risk of concussion in boxing

Study period	Source population	Denominator	Injury definition & number of concussion	Author's Incidence [1st author of the study]	Recalculated incidence & 95% confidence intervals (CI)*
1982 – 1983 & 1983-1984	Professional boxers in New York State	3,110 rounds (1,636 from 82-83 and 1,474 from 83-84).	Any technical knockout or knockout from head blows. Total of 262 craniocerebral injuries (138 from 1982-3; 124 from 1983-4)	0.8 /10 rounds (2.9 injuries/10 boxers from 1982-3 and 2.9 injuries/10 boxers from 1983-4) [Jordan, 1988].	Overall 0.8 (95% CI, 0.75-0.95)/10 rounds; 0.8 (0.71-0.99)/10 rounds for 1982-3; 0.8 (0.70-0.99)/10 rounds for 1983-4.
Nov. 1992-May 1993	Amateur boxing competitors in Dublin, Ireland	4,170 man-minutes for competitions. Not reported for training sessions.	The early stoppage of the contest, and/or time loss, and/or preventing competing maximum potential. Overall 33 concussions.	51.6% in competitions; 0% in training [Porter, 1996].	7.9 (95% CI, 5.45-11.09)/1,000 man-minutes in competition.
1983-1984 & 1984-1985	US Military Academy in West Point, New York (males)	23, 625 hours for instructional program; 1,680 hours for competitive phase program	Excused from physical activity for more than one day. Total of 22 concussions (18 from the instructional phase and four from the competitive phase).	[Welch, 1986].	0.76 (95% CI, 0.45-1.2)/ 1,000 hours for instructional phase; 2.4 (0.65-6.1)/1,000 hours for competitive phase.

* Incidence was recalculated in some cases. We also calculated 95% CI's if not presented in an original paper.

Table 4-4. Summary of study characteristics of risk of concussion in ice hockey

Study period	Source population	Denominator	Injury definition & number of concussion	Author's incidence [1st author of the study]	Recalculated incidence & 95% Confidence Intervals (CI)*
Two consecutive seasons	14 randomly chosen Danish elite hockey teams	Training time of 5.3 hours a week over eight months; playing time of 50 minutes per player per week in five months; 18 matches 60 minutes per season.	Hindered activity, and/or required special treatment. Total of 27 concussions; six from training; 21 from matches.	14.3 % [Jørgensen, 1986].	0.16 (95% CI, 0.06-0.35)/1,000 training-hours; 6 (95% CI, 3.7-9.2)/1,000 game-hours.
Three days (1994)	High schools in Minnesota (1994 Junior Gold ice hockey tournament, males)	1,099 athlete- exposures; 213.9 player-hours.	Requiring assistance from the athletic trainer and time loss. Total of four concussions.	[Roberts, 1996]	18.7 (95% CI, 5.1-47.1)/1,000 player-game hours; 3.6 (95% CI, 0.99-9.29)/1,000 athlete exposures.
1988-1992	Swedish elite ice hockey league.	7,536 player-game hours (approximately 70% of all player-game hours in the league during four seasons).	Concussion with loss of consciousness. Total of 52 concussions.	[Tegner, 1996]	6.9 (95%CI, 5.2-9.0)/1,000 player-game hours.

* Incidence was recalculated in some cases. We also calculated 95% CI's if not presented in an original paper.

Table 4-4. Continued

Study period	Source population	Denominator	Injury definition & number of concussion	Author's incidence [1st author of the study]	Recalculated incidence & 95% confidence intervals (CI)*
Sept. 1979-May 1985	Canadian Intercollegiate ice hockey (males)	9,424 player-games (including league and non-league).	Professional attention or time loss. Total of 52 concussions.	6% [Pelletier, 1993].	6.9 (95%CI, 5.2-9.0)/1,000 player-game hours.
1993-1994 season	High school varsity, Junior Gold (males); Girl's Peewee in Minnesota (females)	511.2 player-game hours (PGH), 2,320 athlete exposures (AE) for males (86.4 PGH, 401AE for Peewee A; 93.6 PGH, 410AE for Bantam A; 108 PGH, 410AE for High school; 223.2PGH, 1,099AE for Junior Gold); 79.2 player-game hours, 357 athlete exposures for Girl's Peewee A&B.	Injury evaluated by the medical personnel, time loss, or dental injury (NAIRS† and CAIRS‡ (Pelletier, 1992)). Total of nine concussions.	17.6/1,000 player-game hours during boy's games (Peewee boys, 23.1/1,000 PGH; Bantam, 10.7/1,000 PGH; Junior Gold, 18.7/1,000 PGH; High school varsity, 18.5/1,000 PGH) [Roberts, 1999].	17.6 (95% CI, 8.1-33.2)/1,000 player-game hours during boy's games; 3.9 (1.8-7.4)/1,000 athlete-exposures.

* Incidence was recalculated in some cases. We also calculated 95% CI's if not presented in an original paper.
†NAIRS: National Athletic Injury Reporting System.
‡CAIRS: Canadian Athletic Injury/Illness Reporting System.

Table 4-5. Summary of study characteristics of risk of concussion in karate

Study period	Source population	Denominator	Injury definition & sample size	Author's incidence [1st author of the study]	Recalculated incidence & 95% confidence intervals (CI)*
1976-1979, 1982.	Six national/inter-national Karate tournaments: (males from 14 countries).	309 matches.	Grade 1: injured, but able to continue competition; Grade 2: injured and forced to withdraw from competition; Grade 3: injured and required hospitalization. A total of one concussion.	[Stricevic, 1983].	618 athlete-exposures; 3.24 (95% CI, 0.08-17.89)/1,000 matches or 1.62 (0.04-8.98)/1,000 athlete-exposures.

* Incidence was recalculated in some cases. We also calculated 95% CI's if not presented in an original paper.

Table 4-6. Summary of study characteristics of risk of concussion in taekwondo

Study period	Source population	Denominator	Injury definition & number of concussion	Author's incidence [1st author of the study]	Recalculated incidence & 95% confidence intervals (CI)++
1988-1991	US National Senior Championships & US Team Trials (males & females)	3,408 AE, 25,383 ME for males; 1,654 AE, 12,961 ME for females.	Assistance was sought from medical personnel and Nelson et al.'s concussion classification used (Nelson et al., 1984). 28 concussions (24 for males & four for females).	7.04/1,000 athlete exposures, 0.95/1,000 minute exposures for males; 2.42/1,000 athlete exposures, 0.31/1,000 minute exposures for females [Pieter, 1998].	7.04 (95% CI, 4.5-10.46)/1,000 AE and 0.95 (0.61-1.41)/1,000 ME for males; 2.42 (0.66-6.18)/1,000 AE and 0.31 (0.08-0.79)/1,000 ME for the females.
1991	World Championships (49 countries, males & females)	Raw exposure data not reported.	Serious injuries that lead to time-loss and Nelson et al.'s (Nelson et al., 1984) concussion classification used. Nine concussions (eight males and one female).	15.27/,1000 athlete exposures for males; 3.23/1,000 athlete exposures for females [Pieter, 1994].	Approximately 523.90 AE for males and 306.60 AE for females. 15.3 (95% CI, 6.6-29.86)/1,000 AE for males; 3.2 (0.08-18.07)/1,000 AE for females.
1993	European Cup (16 countries, males & females)	258 AE for males; 114 AE for females.	Injuries that occurred in the ring or during the warm-up that were brought to the attention of the medical personnel. Five concussions (four males and one female).	15.50/1,000 athlete exposures for males; 8.77/1,000 athlete exposures for females [Pieter, 1995].	15.5 (95% CI, 4.24-39.2)/1,000 AE for males; 8.77 (0.22-47.9)/1,000 AE for females.

Table 4-6. Continued

Study period	Source population	Denominator	Injury definition & number of concussion	Author's incidence [1st author of the study]	Recalculated incidence & 95% confidence intervals (CI)*
1989-1990	US National Junior & unofficial Junior World Championships (males & females)	6,068 AE†, 21, 894 ME‡ for boys; 1,538 AE, 5,855 ME for girls	Discontinuing the present bout and/or subsequent bouts and practice. 38 concussions (31 boys and seven girls).	5.11/1,000 AE for boys; 4.55/1,000 AE for girls [Pieter, 1999].	5.1 (95% CI, 3.47-7.24)/1,000 AE and 1.42 (0.96-2)/1,000 ME for boys; 4.6 (1.83-9.36)/1,000 AE and 1.2 (0.48-2.46)/1,000 ME for girls.
1999	14th World Championships (66 countries, males & females).	596 AE, 5,304 ME for males; 422 AE, 3,786 ME for females.	A trauma induced alteration in mental status that may or may not involve loss of consciousness. Eight concussions (six males and two females).	10.07/1,000 AE, 1.13/1,000 ME for males; 4.7/1,000AE, 0.53/1,000 ME for females [Koh, 2001].	10.1 (95% CI, 3.7-21.8)/1,000 AE and 1.1 (0.4-2.5)/1,000 ME for males; 4.7 (0.6-17)/1,000 AE and 0.5 (0.06-1.9)/1,000 ME for females.

* Incidence was recalculated in some cases. We also calculated 95% CI's if not presented in an original paper.
† AE: Athlete Exposures.
‡ ME: Minute Exposures.

Table 4-7. Summary of study characteristics of risk of concussion in rugby

Study period	Source population	Denominator	Injury definition & number of concussion	Author's incidence [1st author of the study]	Recalculated incidence & 95% confidence intervals (CI)*
1996	The first team at one professional rugby league club (European Super League season, United Kingdom)	596.5 player-hours for winter; 397.67 player-hours for summer.	Impairment preventing participation in the next competitive game. Total of nine concussions (eight winter and one summer).	3.35/1,000 player-hours in winter†; 2.51/1,000 player-hours in summer [Gissane, 1998].	9.05 (95% CI, 4.1-17.1)/1,000 player-game hours: 13.41 (95% CI, 5.8-26.23)/1,000 player-game hours in winter; 2.51 (0.06-13.95)/1,000 player-game hours in summer.
1979 rugby union season	Club and representative matches at Ballymore in Brisbane.	221 matches, 8,365 player-hours.	Any period of unconsciousness, confusion, amnesia, unsteadiness or altered vision whether or not neurological signs are present. Total of 24 concussions.	[Myers, 1980].	2.87 (95% CI, 1.84-4.27)/1,000 player-hours.
1979, 1980, 1982	Senior Victorian Football League players, Australia.	29,568 game-hours.	Attention of the club medical officer, requiring active treatment and interfering with subsequent play or training. Total of 74 concussions.	[Dicker, 1986]	2.5 (95% CI, 1.9-3.1)/1,000 player-game hours

Table 4-7. Continued

Study period	Source population	Denominator	Injury definition & number of concussion	Author's incidence [1st author of the study]	Recalculated incidence & 95% confidence intervals (CI)*
1989-1991	Three teams of the South Sydney Rugby League Football Club (only games).	3,140 player-position game hours.	A player missing subsequent games. Total of 74 concussions.	[Gibbs, 1993].	1.6 (95% CI, 0.52-3.71)/1,000 player-position game hours.
1990-1994	One professional rugby league club in United Kingdom (only games).	4,305.21 player-hours. A total of 249 games.	Concussion with or without loss of consciousness and memory problems. Total of 35 concussions.	8 (95% CI, 6 -11)/1,000 player-hours [Stephenson, 1996].	
Sept. 1950-Dec. 1979	Rugby School	500,000 player-hours.	Injury led to at least one week's absence from the game. Total of 513 concussions.	[Sparks, 1981].	10.26/10,000 player-hours or 1.03 (95% CI, 0.94-1.12)/1,000 player-game hours.

* Incidence was recalculated in some cases. We also calculated 95% CI's if not presented in an original paper.
† Calculation of the winter concussion rate is not correct based on the given denominator (596.5 player hours).

Table 4-8. Summary of study characteristics of risk of concussion in soccer

Study period	Source population	Denominator	Injury definition & number of concussion	Author's incidence [1st author of the study]	Recalculated incidence & 95% confidence intervals (CI)*
1995-1997	235 United States high schools (males & females)	7,539 player-seasons for boys; 5,642 player-seasons for girls.	Cessation of participation for initial observation and evaluation before returning to play. Total of 69 concussions for males and total of 76 concussions for females.	0.18 (95% CI, 0.14-0.22) /1,000 athlete exposures, 0.04 (0.01-0.06) /1,000 practice exposures, 0.57 (0.43-0.72) /1,000 game exposures for males. 0.23 (0.18-0.28) /1,000 athlete exposures, 0.05 (0.02-0.08) /1,000 practice exposures, 0.71 (0.53-0.88) /1,000 game exposures for females [Powell, 1999].	
Seven weeks (year?†)	A local indoor soccer arena (United Sates Soccer Federation regulations for indoor soccer, males & females)	2,700 player-hours; 1,548 player-hours for males; 1,152 player-hours for females.	Injury requiring medical attention and stopped the game. Two concussions in males	[Lindenfeld, 1994].	0.13/100 player-hours for males or 1.3 (95% CI, 0.16-4.66)/1,000 player-game hours for males.

* Incidence was recalculated in some cases. We also calculated 95% CI's if not presented in an original paper.

† ?: Not reported or not clearly reported

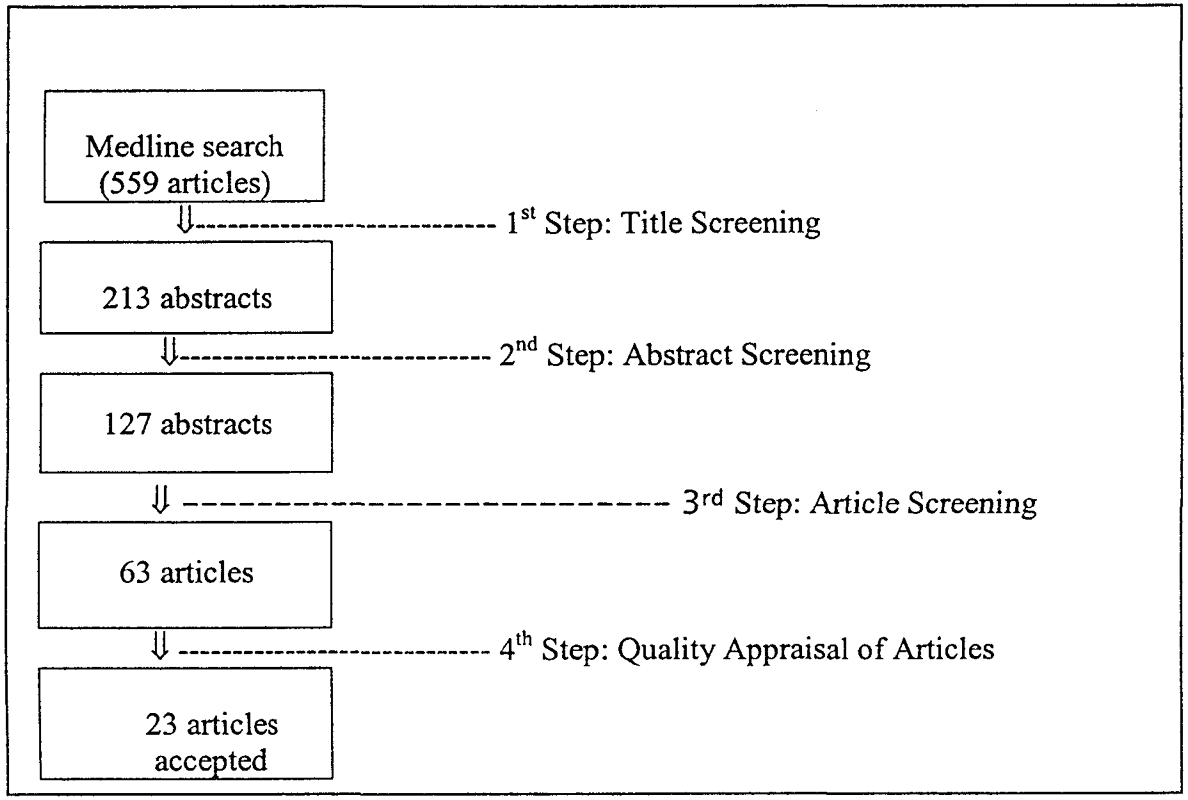

Figure 4-1. Paper search procedure and results

CHAPTER 5

Concussions following a head blow in competition Taekwondo

INTRODUCTION

In competition Taekwondo[1], blows to the head region occur commonly, since the face is a major scoring region. Several studies have reported injuries to the head and face region in Taekwondo tournaments, including contusion, laceration, facial fracture, dislocation, and concussion. Among these conditions, there are growing concerns with respect to concussion, since concussion may result in cognitive dysfunction such as memory problems (Master, Kessels, Lezak, Troost, & Jordan, 2000), and its effect may be cumulative (Gaetz, Goodman, & Weinberg, 2000; Sortland & Tysvaer, 1989; Yarnell & Lynch, 1973).

Our three previous studies will briefly be reviewed since they indicate some issues that are required to be verified in the future studies. The first study documented overall injuries in the world class of competition Taekwondo. Eight competitors (7.86/1,000 athlete-exposures; 6 for males and 2 for females) experienced concussion from this competition. All of the concussed competitors showed one of the noticeable signs of concussion. We concluded that the incidence rate of concussion in this analysis is low, but the results might be limited by unreporting of cases, language difficulties, and the reluctance of world-class competitors to take part in research projects at such an important tournament. However, there remains questions about whether our rate is in fact an underestimate of concussions in competition Taekwondo.

[1] Competition Taekwondo refers to full contact sparring.

In the second study, we analyzed videotapes of head blows in the same competition to determine a method for describing the events leading up to head blows that might produce injury. We found a significant number of head blows (365 head blows/1,000 athlete-exposures from 19 competitors) which could have caused a high potential for mild traumatic brain injury at the tournament. We also documented potential offensive and defensive techniques that might be used to reduce or prevent serious head blows. Although we observed a number of head blows during semi and final matches, the frequency of head blows in the whole tournament and whether or not these head blows cause concussion, still needs to be determined.

In the third study, we reviewed the incidence of concussion in eight contact sports using a systematic method. Overall, ice hockey and rugby have the highest incidence of concussion and soccer has the lowest. Male boxers and female Taekwondo competitors have the highest frequency of concussion at the recreation level. In the review, we identify some common methodological problems with the hope of improving future studies. Additionally, we indicate the possible underestimation of the true incidence of concussion in sports due to methodological bias.

The general focus of this chapter is to examine the frequency of concussion following a head blow and to determine other potential factors related to these incidents in Korean competitors. There are several reasons why the present study is necessary. There are limited published studies regarding head blows and concussion in competition Taekwondo. Also, several issues arising from our previous work need to be answered in this research. Moreover, there are no published studies regarding these issues in Korea, where Taekwondo is the national sport. Furthermore, the young competitors of the present study make up the largest proportion among all age groups in competition Taekwondo. In addition, no studies have been conducted in a general black belt class in competition Taekwondo. Finally, there are no previous studies that have used direct observation combined with subject interview using a prospective design. It is important to quantify the frequency of head blows and to investigate the receiver's experiences at the time of head impact and post-impact.

Therefore, the purpose of the present research is to quantify the frequency (incidence) of head blows and to examine the frequency of possible concussions following these head blows. Another aim of the study is to examine which factors are independently associated with head blow and concussion. Finally, through visual analysis of competition videotapes, we examine the situational and contextual factors surrounding head blows, with a view to making recommendations that might reduce their frequency.

METHODS

Participants and definition of concussion

Data were collected at the 12th middle and high school Taekwondo tournament on July 22-31, 2001 in Soo-Won, South Korea. A total of 2,328 athletes (676 females and 1,652 males) from 424 schools participated in the tournament and ranged in age from 11-19 years. This tournament is one of the largest tournaments in this population.

The definition of concussion used in the present study is "a traumatically induced physiological disruption of brain function with a short period of altered or loss of consciousness" (The Mild Traumatic Brain Injury Committee of the Head Injury Interdisciplinary Special Interest Group of the American Congress of Rehabilitation

Medicine, 1993). The case definition of potential concussion includes any athlete who has had a direct blow (blunt trauma by a kick) to the head/face region that induces physiological disruption of brain function. They must have experienced at least one of the following: any period of loss of consciousness (30 minutes or less); any loss of memory for events immediately before or after the injury (posttraumatic amnesia not greater than 24 hours); any alteration in mental state at the time of the injury (e.g., feeling dazed, disoriented, or confused); or focal neurological deficit(s) that may or may not be transient. When the impact caused facial/skull fractures, the case was excluded from this study.

General description of data collection

Figure 5-1 shows procedures for overall data collection. The procedure consisted of three separate tasks: (a) collection of general information (see Appendix D) for all participants prior to their matches; (b) collection of head blow cases and concussion cases (see Appendix E); and (c) videotape recording for all head blow scenes at the tournament site. The tournament is a single elimination competition and competitors wore head and chest protection, arm and shin pads, groin protectors and mouth-guards (optional).

A simple structured interview check-off form for a head blow/concussion case was used (Appendix E): It recorded gender, years of training/competing in taekwondo, weight division, weight loss before the competition, height difference between competitors, time of head impact, common concussion signs (knockdown and knockout/loss of consciousness), symptoms at the time of head impact and post-impact, history of past significant head blows and/or concussions, blocking skill and mouth-guard use. In addition, the factors associated with head blows and concussions were recorded and analyzed on videotapes.

For videotape analyses, tapes of bouts containing all head blows were labeled and stored for later analysis. The head blow video analysis form (coding sheet, see Figure 3-1 in Chapter 3) contained head impact situation/mechanism, including technique that caused any injury or head blow, fighting type/sparring stance, attempted evasive maneuvers (i.e., blocking skills or other), anatomic impact site, the presence of a double or multiple impact, head movement post-impact, and any changes in balance or gait post-impact. All characteristics above were each identified so that a full description of events leading up to and following head impact could be characterized.

Inclusion of a head blow event in this study required that at least one of the following occurred after a direct blow to the head/face region: 1) the head is caused to move rapidly due to the impact; 2) one demonstrates a stunned or dazed state; 3) the referee is required to call "standing down" (usually 8-count); 4) the opponent is awarded a point; 5) one demonstrates gait unsteadiness (an ataxic, stumbling, off-balance, or unsteady gait with a tendency to fall); 6) one received a blow to any body region and then one's head region contacts the playing surface as a result of falling; or 7) any loss of consciousness. When no head movement occurred following a head blow (due to insufficient power from the kick or punch or insufficient contact to the head/face region), the blow was excluded. These criteria were also used by two independent observers when evaluating inter observer agreement of each head blow scene, with the exception of the fourth criterion (i.e. the opponent is awarded a point for the success of the head blow) because the tape did not contain the score of matches.

Procedure

For head blow/concussion cases:

A video recorder and one tournament observer observed at every match and recorded the occurrence of head blows at each ring. When a tournament observer noted a significant head blow, he recorded the time of the blow, colour of chest gear (e.g., red or blue), and bout (site of ring number/court) in which the blow occurred, and then reported the case to one of the athletic trainers or the researcher. At the conclusion of the match, the competitor who received the head blow was asked to go to the medical site or interview site, where data were collected by project staff. The athletic trainers and researcher interviewed the athletes who received the head blow at the tournament site (Appendix E). In the month following the tournament, the videotapes were reviewed and coded according to the procedure developed in Chapter 3.

Statistical analyses

In this tournament, the single elimination and semifinals were three rounds, lasting one and a half minutes per round, while the final three rounds lasted two minutes. To calculate actual match time, competitors who did not complete all three rounds were noted and actual sparring time was recorded. Injury incidence rates were calculated using the basic rate formulas: (1) (number of injuries / number of athlete-exposures) x 1,000 = number of injuries per 1,000 athlete-exposures; (2) (number of injuries / number of minutes of exposures) x 1,000 = number of injuries per 1,000 minutes of exposure. This calculation has been utilized by Zemper and Pieter (1994). One athlete-exposure refers to one person being exposed to the possibility of sustaining an injury. During one

Taekwondo match, there are two athletes competing at the same time (Pieter & Lufting, 1994). Also, we calculated 95% confidence intervals around these rates.

Multinomial logistic regression was used to examine associations between the explanatory factors and groups. There were three different groups in the dependant variable: **Group 1**: those that did not received head blow; **Group 2**: those that received head blows that did not result in a concussion; and **Group 3**: those that received a head blow resulting in a concussion. Independent variables were education level, age, gender, weight loss, weight division (combined into four categories), years of training in taekwondo, years of competing in taekwondo, past history of concussion, past history of head blow, usage of mouth-guard, and usage of blocking skill. Prior to performing statistical modelling, the frequency of study variables was assessed, and then crude multinomial logistic models were built to examine associations between each explanatory factor and the three groups. Factors with less than 10% missing cases were considered in the multivariable logistic model. Also, variables that were statistically significant in the crude multinomial logistic models were included in the final multivariable multinomial logistic model. In addition, the factor of mouthguard usage was excluded because only 31 (1.5%) out of total participants used the mouthguard. Furthermore, age was not included in these analyses since age and education level were highly correlated ($r = 0.83$). Therefore, education level, gender, weight category, years of competing taekwondo, past head blow, and usage of blocking skill were entered into the multivariable logistic model. Only those variables that were statistically significant were retained in the final model. The Group 1 (no head blow group) was used as the reference category. All analyses were performed with the alpha level set at 0.05 using SPSS 11.0. For the videotape analysis, inter observer agreement on the head blow occurrence was assessed by two independent observers using the Kappa statistic (Gordis, 2000). Only the cases of head blow, which were agreed by two independent observers and analysed using the head blow criteria mentioned earlier, were used for further analysis. This study was reviewed by the Research Ethics Board of the Faculty of Physical Education and Recreation and assessed as meeting the standards of the Canadian Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans (Appendix C).

RESULTS

General information by self report

A summary of the mean age, training years, and competition year in taekwondo is presented in Table 5-1. A total of 1,673 (approximately 72% of the total 2,328 competitors) participants completed the competitors' general information form. Six hundred and fifteen contestants out of 1,625 respondents (38%) lost weight within two weeks prior to the tournament. 1,155 competitors out of 1,616 respondents (72%) had a prior history of receiving a head blow during the previous 12 months. Among these competitors, 732 (63%) reported that they experienced one of the concussion signs and symptoms, such as loss of consciousness, feeling dazed or stunned, headache, and/or dizziness right after the head blow. Based on this self-report, 640 competitors (approximately 40%) experienced a concussion from participating in Taekwondo or other activities such as mishaps during the last 12 months. Of these 640 participants, only 109 participants (17%) identified that they had a concussion. Ninety-eight percent of participants reported that they do not use a mouthguard during training and/or competition. Also, 89% of participants reported that they usually use blocking skills when they are receiving attacks during sparring.

Table 5-2 shows the frequency of all head blows, head blows without concussion, concussions, and exposure data. The totals of athlete-exposures and actual minute-exposures were 4,564 and 20,315, respectively. Overall incidence rates for head blows were 226 [95% CI: 214-239] head blows per 1,000 athlete-exposures and 51 [95% CI: 48-54] head blows per 1,000 minute-exposures. The rates for concussion were 50 [95% CI: 44-57] concussions per 1,000 athlete-exposures and 11 [95% CI: 10-13] concussions per 1,000 minute-exposures. From all head blows including concussion cases, we identified 669 (85%) head blow recipients and interviewed 572 (73%) of them at the tournament site. Ninety-seven (12%) of those who received a head blow refused our interview.

Table 5-3 shows the distribution of head blows and concussions by weight division. The highest frequency of head blow occurred in the fin weight class at the high school level and in the welter weight class at the middle school level for both genders. For the high school competitors, the highest occurrence of concussion was in the bantam weight for both males and females. For middle school males and females, the welter weight division sustained the highest frequency of concussion.

The time of head blow occurrences was evenly distributed throughout the day. However, the highest frequency (48 individuals, 21%) of concussions occurred between 11:01 to 12:00 a.m.. Forty-two percent of both head blow receivers and concussed athletes reported that their levels of sparring skill were similar to their opponent. Forty-four percent of concussed athletes reported their levels of sparring skill to be inferior to their opponent. Most head blows and concussions (96%) took place in single elimination matches. Fifty 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. On average, only 33% of both head blow recipients and concussed competitors anticipated that he or she might receive a head/face blow from the opponent.

Among athletes who received a head blow and did not experience a feeling of being dazed or stunned at the time of impact, 24 (8%) reported having one other concussion symptom. The common symptoms were ringing in the ear (50%), headache (29%), and nausea (17%). Nevertheless, 70 concussed competitors (31%) reported not having any post concussion symptoms at the time of interview. Table 5-4 presents the distribution of symptoms experienced by concussed competitors. The most common complaints were dizziness, confusion, and ringing in the ear. Fifty-eight (37%) of concussed competitors had more than one concussion symptom. Of concussed competitors, 87 competitors (39%) had injuries to other body parts including the head and neck (seven competitors, 9%); upper body (11 competitors, 13%); and lower body (64 competitors, 78%). Of these injured competitors, 62 athletes (75%) had a single injury and 21 athletes (25%) had multiple injuries due to sparring. There were no facial fractures or skull fractures associated with a head blow.

From videotape screening, a total of 1,111 head blow scenes including concussions were identified. Of these, 1,009 head blow scenes were agreed to be significant head blows based on the head blow criteria by two independent observers. The inter-observer reliability was 84% using the Kappa statistic. Only 1,009 of the 1,111 head blow events were used for further analysis. Tables 5-5 to 5-7 show the distribution of head blows and concussions by observed features, total number of head blows, and situations.

From both videotape and the tournament observation, it was apparent that three competitors lost consciousness following impact to the head. The length of time the athletes remained unconscious was less than one minute for all three competitors. A total of 58 knocked down events and 254 events of gait unsteadiness were observed after a head blow amongst the athletes who received a head blow without sustaining a concussion. However, there were no other apparent physical changes observed from the 89 (39%) concussed competitors post head blow. Overall, 207 (28%) of competitors received more than one significant head blow in the tournament (Table 5-5, 5-6).

Overall, there were 402 (44.3%) head blows including concussions sustained by an opponent's counter attack (Table 5-7). The rest of the 338 head blows, including concussions, involved no reaction to a head strike. From all head blow recipients, we observed only 13 (1%) athletes attempting to use blocking skills, even though they were unsuccessful.

Tables 5-8 to 5-10 present the frequency of head blows with and without concussion by sparring stance, kicking techniques, and anatomical site of the head blow impact. The most common situation of a head blow and concussion was when the attacker was situated in closed sparring stance (65%), with a single kick (89%), and with a type of roundhouse kick (51%). In addition, while both contestants were in clinched sparring position, only axe (61%) and roundhouse kicks (39%) caused concussions. Fifty-two percent of head blows were made by the attacker's left foot and 48% by the right foot. For the cases of concussion, 44% were made by the attacker's left foot and 56% by the right foot. Among those concussed competitors, 33% reported that they had anticipated receiving a head blow from their opponents.

The most frequent anatomical site of head impact was the side of the head (temporal region, in 75%) in overall head blows with and without concussion (Table 5-10). Among concussed competitors who experienced the symptom of ringing in the ear, 61% of impacts to the head were made on the side of the head and face, 16% on the lower jaw, 13% on the back of head, and 10% on the center of the face.

A total of 131 referee's counts[2] were called among all head blows, including concussions. Of these, 86 referee counts were called among the head blow recipients without concussion.

The frequency of concussions occurring when the attacker's heights were similar was 41%, followed by taller in 39%, and shorter in 20%. Similarly, this pattern and ratio was observed in the head blow recipients. Among the concussed athletes, 75% lost the match and 25% won the match. The recipients of a head blow showed similar results with 70% losing the match and 30% winning the match. Thirty-five (15%) concussed competitors and sixty-three (11%) head blow recipients did not complete all three rounds of the match.

Variable frequencies and crude multinomial models for all variables are presented in Table 5-11 and Table 5-12, respectively. The multivariable model of the six selected variables for the multinomial model is presented in Table 5-13. The final multivariable logistic model (Table 5-14) showed that there were important differences between Group 1 and Group 3 in terms of education levels and usage of blocking skills. In other words,

[2] This is one of the procedures in the event of a knock down or dangerous situation. The referee judges that the competitor cannot continue as the result of any power technique having been delivered. Usually, the referee counts aloud from one to ten.

middle school competitors were more likely to get a concussion. Also, the competitors who were using blocking skills were less likely to get a concussion. On the other hand, there were significant differences between Group 1 and Group 2 with respect to education levels, past history of head blows, and usage of blocking skills. The competitors who had a past history of receiving a head blow were less likely to get a head blow.

DISCUSSION

The findings from the present study are significant in terms of identifying the incidence of concussion associated with direct head contact, and describing the fighting context in which such head blows occur. In the current research, there was more 'surveillance' of the participants by observers, direct interviews, and videotapes than in other studies where only self-reports were used. Also, follow-up with videotape recording for all fights supports evidence on under-reporting of possible injury cases. This primary information may be valuable for conducting similar future studies, and for developing research questions, better methods, and injury reduction/prevention strategies. Moreover, the results of the present study may be useful to athletes, coaches, and referees in terms of reducing injury in this sport.

In middle school and high school competition Taekwondo in Korea, approximately one of every 10 participants is likely to experience an impact to the head that leads to feeling dizzy, dazed or stunned, and may be accompanied by other symptoms such as headache or nausea. Based on our case definition of concussion, 229 concussions occurred in 227 competitors of a total of 2,328 participants due to a direct blow to the head. Compared to other previous reports on the incidence of concussion in this sport (Pieter & Zemper, 1999,1998), the present research shows the highest incidence of concussion (9.8%, 50 concussions per 1,000 A-E). However, when compared to our previous study (Koh & Watkinson 2002, in press) on the frequency of head blows, the current study shows a lower frequency of head blows (365 head blows versus 226 head blows per 1,000 A-E). The reason for this discrepancy is probably shorter exposure times for the current study (1.30 minutes versus 3 minutes for each round). When taking into account the total minute-exposures, the incidence rate in the present study is actually higher. In addition, the multinomial logistic model showed that middle school competitors were more likely to get a head blow and concussion than high school competitors.

When compared with other contact/collision sports (Koh, Cassidy, & Watkinson 2002 in Chapter 3, submitted for publication), competition Taekwondo results in the highest incidence rate for concussion. Possible reasons for this include the different methods of data collection and the different definitions of concussion or injury used. Another reason is the likelihood of under reporting or under estimation of the incidence of concussion in previous studies. Koh and Watkinson (2002, in press) and Grindel, Lovell, and Collins (2001) suggest possible under reporting of the incidence of concussion in their studies due to athletes who do not experience a loss of consciousness or do not seek medical care. A study by Delaney, Lacroix, Leclerc, and Johnston (2000) found that small numbers (18.8%) of football players recognized that they had experienced a concussion. A similar result (17%) was also found in this present study using self-report of concussion. The results of these studies imply that there is potential under estimation of the incidence rate of concussion in other sports due to a lack of recognition by athletes themselves and by others, particularly, when the concussion occurs without loss of consciousness or obvious signs and symptoms. An additional and obvious explanation of our high rate of concussion is that the current study used "case finding" and our definition of concussion is very "liberal". From our videotape observation, it was surprising that no abnormal physical alterations or movements were observed in 48% of concussed athletes immediately following a significant head impact.

Approximately 34% of concussed athletes received more than one significant head blow during the same match. However, we are not certain whether concussion accompanied one of these blows, or whether the concussion was the outcome of more than one blow. Only two competitors identified that they had experienced another concussion from another match. Rabadi and Jordan (2001) reviewed several studies on the cumulative effect of repetitive concussion in sports. They concluded that although the long-term effects of multiple concussions are controversial, there are possibilities of cumulative effects of repetitive concussions. Also, they suggested that minimizing the number of these exposures is required for a safety reason. In addition, studies conducted by Barth et al. (1989) on the effects of sustaining multiple head blows and by Master, Kessels, Lezak, Jordan, and Troost (1999) on neuropsychological impairment in amateur soccer players indicate that long-term deficits are associated with the cumulative effect of multiple head blows. Another study conducted by Gaetz et al. (2000) found that junior hockey players with three or more concussions differed significantly on the several cognitive post-concussion symptoms and the latency of the P3 response compared to those with no concussion history. On the other hand, studies conducted by Collins et al.

(1999), Macciocchi, Barth, Alves, Rimel, and Jane (1996), Maddocks and Saling (1996), and Maddock and Saling (1995) found that players with concussion showed impaired neuropsychological performances for a few days to two weeks after concussion in comparison to controls, but did not suffer long-term effects. To verify the effects of multiple head blows, further research is necessary in competition Taekwondo.

The types of kick that most commonly caused a concussion were the roundhouse kick (50%, particularly by the simple roundhouse kick), followed by the axe kick (33%, particularly by the outside-in axe kick), the back kick (8%, by the jumping back kick), and the spinning kick (6%, by the jumping spinning kick). The side kick showed the lowest frequency leading to a concussion. Similar results were found in previous studies. Koh et al. (2001) reported the predominant kick causing concussion was the roundhouse kick. Another study conducted by Pieter, van Ryssegem, Lufting, and Heijmans (1995) confirmed that the roundhouse and spinning kicks incurred the highest number of concussions at the 1993 European Taekwondo Cup. This may be due to the fact that the roundhouse kick is the fastest kick (Serina & Lieu, 1991; Chuang & Lieu, 1992) compared to other taekwondo kicks and also the most frequently used kick in competition Taekwondo. Additionally, a small proportion of concussions occurred by the jumping back kick (16 out of 17 back kicks) and the jumping spinning kick (10 out of 13 spinning kicks) among the head blow recipients. Although these kicks were associated with a lower frequency of concussion than the axe and roundhouse kicks during this competition, these kicks were used mainly during a counter attack.

We have scrutinized the situation leading up to head blows. Forty-four percent of head blow recipients received a blow while engaged in an offensive action (i.e., by the attacker's counter attack). This situation is one which could lead to more serious injury because the resultant blow has the additive force of the attacker's kick as well as the receiver's forward momentum. To prevent serious head injury from the counter attack, the referee's role in discouraging such action presents one option (i.e. according to competition rules, in case of avoiding the match (revised in 2001), "the penalty shall be given to the one more defensive (which means the counter attacker) and steps back more frequently". Put differently, the referee should favor attacks over counter attacks).

As we expected, the same pattern of kicking skills that caused concussions was also observed in the head blows without concussion. However, Koh and Watkinson (2002, in press) observed that the most frequent kick involved in a head blow was the axe kick, followed by the roundhouse kick. Additionally, the cases which rendered knock-outs or gait problems were caused by the roundhouse kick, followed by the spinning kick, and the axe kick.

When the combatants are in the closed sparring stance, the highest frequency of head blows and concussions occurred, followed by clinched sparring stance. Koh and Watkinson (2002, in press) found that 66% of head blows occurred in the closed sparring stance and 31% in open sparring stance. As we indicated in the previous study, the closed sparring position limited visual and physical access to the torso target areas, but not to the face and head region. This is similar in the clinched sparring position. When in a clinched sparring position, the most repeatedly used kicking technique was the axe kick, particularly the outside-in axe kick, the primary target of which is the face region. This axe kick is very practical to use when in very close distances. For example, when two athletes are in a clinched position, there is no ability of targeting a blow to the trunk region, but the head/face region is open. In other words, these two sparring stances protect the torso region from the opponent, leaving the head and face as the primary target for kicks. While these may appear to be good defensive choices, they leave the fighter open to receiving blows to the head that count twice as much and may lead to injury and loss of the match.

Among the total head blows presented in this study, including concussions, 99% of cases did not involve attempting or preparing evasive maneuvers at the time of head impact. The blocking skill (i.e. crossed hands over the chest) that was used by the 13 competitors, however, was misplaced (blocked the torso rather than the head) and inadequate in terms of functional purposes (i.e. could not effectively block the head). This indicates that the majority of athletes were not trained to block effectively, particularly against a kick to the head. Another reason for the lack of evasive maneuvering is that the athletes may not have anticipated the head blow. Moreover, over 50% of coaches did not advise their athletes with regards to protection of the head/face during a match. As seen in Table 5-14, the competitors who used blocking skills were less likely to get a concussion. To reduce or prevent head injury, coaches and athletes need to develop appropriate/practical blocking skills as well as evasive movements. Also, coaches should advise competitors to protect the head region against a possible head blow, particularly when competitors are in clinched sparring position.

To avoid over-estimating the incidence of concussion, we did not include cases where the head blow recipient did not experience feeling dazed/dizzy or stunned at the time of head impact, but who had a headache or other symptoms during the interview. A study by Dikmen, McLean, and Temkin (1986) and Maddocks, Kicker, and Saling (1995) found that the common symptoms of concussion such as headache are experienced by not only head injured people, but also non-head injured people. According to McCrory (1999), approximately 20% of athletes experience sport related headaches unrelated to concussion.

The symptom of ringing in the ear was more frequently reported in this study of competition Taekwondo than other contact sports. This may be related to the site of head impact, the temporal region being the predominate site of impact (75%). Similar results on the frequency of site of impact were found in rugby and Australian rules football (McIntosh, McCrory, & Comerford, 2000).

In this tournament, we observed only three cases of loss of consciousness despite a number of significant head blows. This low ratio is likely the results of early termination of the bouts by the referees. The referee's decision to stop the match was based on incompatible sparring skill level. The low ratio of loss of consciousness to incidence of head blow supports the crucial role for the referee in preventing and reducing serious injury in competition Taekwondo. Such an appropriate action is also recommended when one receives more than one significant head blow during the same match.

Although this research is the first study to examine the possibility of sustaining a concussion following a significant head blow in competition Taekwondo, it is limited in determining the exact incidence rate of concussion due to the number of athletes who refused the interview and missed the interview. This limitation should be considered when interpreting the results of the current study. Also, we found only two competitors who have had two concussions sustained from two different bouts. We could not identify the remaining cases of possible multiple concussions when concussed competitors received more than one head blow during the same bout. To investigate this problem, further research is necessary.

Although there are limited pertinent studies on the frequency of head blows, the frequency in this study was more than our previous study (Koh & Watkinson 2002, in press) in terms of the length of time exposures. One reason for this is the institution of a rule change in 2002, whereby an attack to the head/face region is awarded two to three points and prior to 2002, one point. Therefore, most competitors in the 2001 tournament trained to attack the head/face region. Further research can verify any trend in the frequency of head blow and concussion after the rule change.

Prevention strategies

With respect to preventive measures for concussion in competition Taekwondo, we have several suggestions based on our findings and the findings of other studies. Firstly, safety education on concussion is needed for athletes and referees. Secondly, competition rules discouraging the counter attack and discontinuing the match after multiple head blows (i.e. after two of 3-points attacks) should be strongly enforced by referees. Thirdly, athletes should practice blocking skills in concert with the offensive/defensive movement. For example, to block roundhouse or axe kicks that are aimed to the side face or head, one arm should be raised over the shoulder (i.e., middle block skills) while training defensive actions, particularly in clinched sparring position, or offensive actions. Another example is to block a blow coming to the center of the face by the back kick/straight axe kick or other straight types, ‘ducking’ as practiced in boxing may be beneficial. Lastly, improvement of the headgear, particularly to protect the temporal area without interfering with side vision might be helpful.

In summary, a total of 1,032 head blows and 229 concussions occurred during one single taekwondo tournament in South Korea in 2001. The middle school competitors were more likely to get a concussion than the high school competitors. Prevalence of concussion during the last 12 months prior to the tournament in this population was approximately 40% that is, 40% of participants had experienced a concussion. The highest occurrence of concussion was in bantam weight for high school for both genders and in welter weight for males and females for middle school. These occurred most frequently between 11:01 to 12:00 a.m.. The incidence of concussion and head blow was associated with direct head or face contact and frequently involved a closed or a clinched sparring stance, an attacker's offensive single kick (particularly roundhouse and axe kicks), head blow recipient's offensive action with absence of a blocking skill, similar or shorter athletes, and single elimination matches. Also, the most frequent site of impact was the side of the head. The common concussion symptoms were dizziness, confusion, and ringing in the ear. Seventy concussed competitors reported not having any symptoms at the time of the interview, which was approximately 10 minutes after the blow. Also, there were no abnormal physical signs and changes observed after a significant head blow in 89 concussed competitors. Overall, 207 competitors received significant multiple head blows.

In conclusion, to prevent or reduce the incidence of concussion in competition Taekwondo, development of blocking skills; updated safety education, including a complete understanding of concussions for athletes, coaches, and referees; rigorous enforcement of the competition rules by the referee; and improvement on the head gear are recommended. Moreover, follow-up research on the incidence of concussion and head blows after competition rule changes are necessary.

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Table 5-1. Summary of mean age (standard deviation), training years, and competing years for 1,673 participants

	H/S* Males (n = 391)	**H/S Females (n = 171)**	**M/S† Males (n = 810)**	**M/S Females (n = 301)**	**Total (n= 1,673)**
Mean age	16.99 (0.96)	16.66 (0.84)	14.07 (0.86)	13.88 (0.85)	**15 (1.62)**
Missing	14	1	36	15	**66**
Mean training years	7.13 (2.84)	6.40 (2.73)	5.82 (2.50)	4.74 (2.54)	**6 (2.72)**
Missing	11	1	29	14	**55**
Mean competing years	4.64 (2.06)	4.36 (1.93)	3.20 (1.58)	2.69 (1.54)	**3.5 (1.88)**
Missing	12	1	30	15	**58**

* H/S: High school.
† M/S: Middle school.

Table 5-2. Incidence rates (95% confidence interval) for head blows and concussions in the year 2001 middle/high school competition

	H/S* Males	**H/S Females**	**M/S*Males**	**M/S Females**	**Total**
Number of athletes	598	268	1,054	408	**2,328**
Number of matches	590	260	1,035	397	**2,282**
A-E†	1,180	520	2,070	794	**4,564**
Actual M-E‡	5,291	2,331	9,201	3,492	**20,315**
Head blows	175	65	542	250	**1,032**
Received a head blow without concussion§	111	45	374	177	**707**
Concussions (Number of persons)	44	17	121	47	**229¶ (227)**
Head blow rate per 100 competitors	29.26 (26-33)	24.25 (19-30)	51.42 (48-54)	61.27 (56-66)	**44.32 (42-46)**
Concussion rate per 100 competitors	7.35 (5-10)	6.34 (4-10)	11.48 (10-14)	11.51 (9-15)	**9.83 (9-11)**
Head blow rate per 1,000 A-E	148.3 (128-170)	125 (98-157)	261.83 (243-281)	314.86 (283-348)	**226.11 (214-239)**
Head blow rate per 1,000 M-E	33.07 (28-38)	27.88 (22.35)	58.9 (54-64)	71.59 (63-81)	**50.79 (48-54)**
Concussion rate per 1,000 A-E	37.28 (27-50)	32.69 (19-52)	58.45 (49-69)	59.19 (44-78)	**50.17 (44-57)**
Concussion rate per 1,000 M-E	8.31 (6-11)	7.29 (4-12)	13.15 (11-16)	13.45 (10-18)	**11.27 (10-13)**

* H/S: High school; M/S: Middle school.
† A-E: Athlete-exposures to the possibility of being injured (2 athletes per bout).
‡ M-E: Minute-exposures (single and semi-final bouts = 1.30 minutes x 3 rounds (4.5) and final bouts = 2 minutes x 3 rounds (6)).
§ Head blows which gained inter observer agreement.
¶ A total number of concussions.

Table 5-3. Frequency (percentage) of head blows and concussions by the weight division

	Group 2: Head blows without concussion				Group 3: Concussion				
Weight class	H/S* male	H/S female	M/S† male	M/S female	H/S male	H/S female	M/S male	M/S female	**Total**
Fin	18 (16.4)	9 (20.5)	41 (11.1)	5 (2.9)	4 (9.1)	1 (5.9)	10 (8.3)	1 (2.1)	**89 (9.6)**
Fly	16 (14.5)	7 (15.9)	41 (11.1)	16 (9.1)	3 (6.8)	1 (5.9)	15 (12.4)	5 (10.6)	**104 (11.2)**
Bantam	16 (14.5)	5 (11.4)	42 (11.4)	16 (9.1)	8 (18.2)	5 (29.4)	19 (15.7)	7 (14.9)	**118 (12.7)**
Feather	11 (10.0)	7 (15.9)	41 (11.1)	24 (13.7)	7 (15.9)	4 (23.5)	18 (14.9)	6 (12.8)	**118 (12.7)**
Light	14 (12.7)	6 (13.6)	46 (12.4)	35 (20)	3 (6.8)	3 (17.6)	5 (4.1)	7 (14.9)	**119 (12.8)**
Welter	12 (10.9)	3 (6.8)	63 (17)	40 (22.9)	6 (13.6)	0	27 (22.3)	12 (25.5)	**163 (17.6)**
Middle	15 (13.6)	3 (6.8)	57 (15.4)	23 (13.1)	6 (13.6)	1 (5.9)	19 (15.7)	4 (8.5)	**128 (13.8)**
Heavy	8 (7.3)	4 (9.1)	39 (10.5)	16 (9.1)	7 (15.9)	2 (11.8)	8 (6.6)	5 (10.6)	**89 (9.6)**
Total	110 (100)	44 (100)	370 (100)	175 (100)	44 (100)	17 (100)	121 (100)	47 (100)	**928 (100)**
Missing events	1	1	4	2	0	0	0	0	**8**

* H/S: High school.
† M/S: Middle school.
Note: The head blows without concussion are based on the videotape analyses for which there was inter observer agreement. Concussions included all those confirmed through interviews, regardless of observer agreement on the tapes.

Table 5-4. Distribution of symptoms experienced by concussed competitors (n = 155)

Symptoms	**Number (percentage) reporting symptoms**
Headache	26 (17%)
Dizziness	103 (67%)
Confusion	49 (32%)
Ringing in the ear	35 (23%)
Nausea	14 (9%)
Vomiting	2 (1.3%)
Vision problems	0

Note: All concussed competitors experienced feeling dazed/stunned/and or dizzy at the time of the head blow or impact.

Table 5-5. Frequency (percentage) of the head blows and concussions by the observed features

	Group 2: Head blows without concussion				Group 3: Concussion				
	H/S* male	H/S female	M/S† male	M/S female	H/S male	H/S female	M/S male	M/S female	**Total**
LOC‡	0	0	0	0	2 (5.4)	0	1 (0.9)	0	**3 (0.3)**
Fall (knocked down/off)	9 (8.2)	3 (6.7)	34 (9.2)	12 (6.8)	9 (24.3)	0	22 (19.8)	5 (11.4)	**94 (10.4)**
Gait unsteadiness	32 (29.1)	15 (33.3)	147 (39.6)	60 (33.9)	11 (29.7)	4 (33.4)	38 (34.2)	23 (52.2)	**330 (36.4)**
No change	69 (62.7)	27 (60.0)	190 (51.2)	105 (59.3)	15 (40.5)	8 (66.7)	50 (45.0)	16 (36.4)	**480 (52.9)**
Total events	110 (100)	45 (100)	371 (100)	177 (100)	37 (100)	12 (100)	111 (100)	44 (100)	**907 (100)**
Missing events	1	0	3	0	1	1	0	0	**6**

* H/S: High school.
† M/S: Middle school.
‡ LOC: Loss of consciousness.

Table 5-6. Frequency (percentage) of the head blows and concussions by total number of head blows

	Group 2: Head blows without concussion				Group 3: Concussion				
Number of head blows	H/S* male	H/S female	M/S† male	M/S female	H/S male	H/S female	M/S male	M/S female	**Total**
One head blow	69 (78.4)	31 (86.1)	208 (74.8)	89 (68.5)	25 (65.8)	9 (75)	73 (65.8)	25 (58.1)	**529 (71.9)**
Two head blows	15 (17)	2 (5.6)	48 (17.3)	36 (27.7)	8 (21.1)	2 (16.7)	32 (28.8)	11 (25.6)	**154 (20.9)**
Three head blows	4 (4.5)	2 (5.6)	19 (6.8)	4 (3.1)	3 (7.9)	1 (8.3)	5 (4.5)	5 (11.6)	**43 (5.8)**
Four head blows	0	1 (2.8)	3 (1.1)	1 (0.8)	2 (5.3)	0	0	2 (4.7)	**9 (1.2)**
Six head blows	0	0	0	0	0	0	1 (0.9)	0	**1 (0.1)**
Total number of athletes	88 (100)	36 (100)	278 (100)	130 (100)	38 (100)	12‡ (100)	111 (100)	43‡ (100)	**736 (100)**

* H/S: High school.
† M/S: Middle school.
‡ Competitors experienced two concussions from another match.
Note: Number of head blow indicated above only occurred.

Table 5-7. Frequency (percentage) of head blows and concussions by the situation

	Group 2: Head blows without concussion				Group 3: Concussion				
Situation	H/S* male	H/S female	M/S† male	M/S female	H/S male	H/S female	M/S male	M/S female	**Total**
Offensive (by counter attack)	54 (49.1)	19 (35.6)	166 (44.6)	65 (36.7)	21 (56.8)	8 (66.7)	46 (41.8)	23 (52.3)	**402 (44.3)**
Defensive	15 (13.6)	10 (42.2)	67 (18)	41 (23.2)	5 (13.5)	2 (16.7)	19 (17.3)	8 (18.2)	**167 (18.4)**
No action	41 (37.3)	16 (22.2)	139 (37.4)	71 (40.1)	11 (29.7)	2 (16.7)	45 (40.9)	13 (29.5)	**338 (37.3)**
Total events	110 (100)	45 (100)	372 (100)	177 (100)	37 (100)	12 (100)	110 (100)	44 (100)	**907 (100)**
Missing	1	0	2	0	7	1	1	0	**6**

* H/S: High school.
† M/S: Middle school.

Table 5-8. Frequency (percentage) of head blows and concussions by the kicking techniques

	Group 2: Head blows without concussion				Group 3: Concussion				
Exact kicking Technique	H/S *male	H/S female	M/S† male	M/S female	H/S male	H/S female	M/S male	M/S female	**Total**
Straight axe kick	9 (8.1)	5 (11.1)	33 (8.8)	21 (11.9)	1 (2.6)	1 (7.7)	9 (8.1)	7 (15.9)	**86 (9.4)**
Inside out axe kick	5 (4.5)	0	7 (1.9)	0	1 (2.6)	1 (7.7)	2 (1.8)	0	**16 (1.8)**
Outside in axe kick	19 (17.1)	9 (20.0)	77 (20.6)	43 (24.3)	2 (5.3)	1 (7.7)	27 (24.3)	6 (13.6)	**184 (20.2)**
Jumping axe kick	8 (7.2)	2 (4.4)	15 (4.0)	5 (2.8)	2 (5.3)	0	6 (5.4)	1 (2.3)	**39 (4.3)**
Simple roundhouse kick	43 (38.7)	22 (48.9)	165 (44.2)	92 (52.0)	22 (57.9)	6 (46.2)	42 (37.8)	21 (47.7)	**413 (45.3)**
Jumping roundhouse kick	4 (3.6)	2 (4.4)	13 (3.5)	2 (1.1)	2 (5.3)	0	4 (3.6)	0	**27 (3.0)**
Double roundhouse kick	6 (5.4)	0	8 (2.1)	2 (1.1)	0	1 (7.7)	2 (1.8)	0	**19 (2.1)**
Turning roundhouse kick	2 (1.8)	0	2 (0.5)	0	3 (7.9)	0	0	0	**7 (0.8)**
Simple spinning kick	3 (2.7)	0	1 (0.3)	0	1 (2.6)	0	1 (0.9)	1 (2.3)	**7 (0.8)**
Jumping spinning kick	4 (3.6)	0	11 (2.9)	3 (1.7)	1 (2.6)	1 (7.7)	5 (4.5)	3 (6.8)	**28 (3.1)**
Simple back kick	2 (1.8)	2 (4.4)	3 (0.8)	0	0	0	1 (0.9)	0	**8 (0.9)**
Jumping back kick	3 (2.7)	1 (2.2)	28 (7.5)	9 (5.1)	2 (5.3)	0	10 (9.0)	4 (9.1)	**57 (6.3)**
Simple side kick	1 (0.9)	2 (4.4)	6 (1.6)	0	0	1 (7.7)	2 (1.8)	1 (2.3)	**13 (1.4)**
Jumping side kick	1 (0.9)	0	2 (0.5)	0	0	0	0	0	**2 (0.2)**
Other	2 (1.8)	0	2 (0.5)	0	1 (2.6)	1 (7.7)	0	0	**6 (0.7)**
Total events	111 (100)	45 (100)	373 (100)	177 (100)	38 (100)	13 (100)	111 (100)	44 (100)	**912 (100)**
Missing events	0	0	1	0	0	0	0	0	**1**

* H/S: High school.
† M/S: Middle school.

Table 5-9. Frequency (percentage) of the head blows and concussions by the sparring stance

	Group 2: Head blows without concussion				Group 3: Concussion				
Sparring stance	H/S* Male	H/S female	M/S† male	M/S female	H/S male	H/S female	M/S male	M/S female	**Total**
Closed stance	76 (68.5)	34 (75.6)	229 (61.4)	119 (67.2)	23 (62.2)	9 (69.2)	70 (63.1)	33 (75.0)	**593 (65.1)**
Open stance	18 (16.2)	6 (13.3)	53 (14.2)	16 (9.0)	8 (21.6)	3 (23.1)	13 (11.7)	5 (11.4)	**122 (13.4)**
Clinched stance	16 (14.4)	5 (11.1)	88 (23.6)	41 (23.2)	6 (16.2)	1 (7.7)	26 (23.4)	6 (13.6)	**189 (20.7)**
Other	1 (0.9)	0	3 (0.8)	1 (0.6)	0	0	2 (1.8)	0	**7 (0.8)**
Total events	111 (100)	45 (100)	373 (100)	177 (100)	37 (100)	13 (100)	111 (100)	44 (100)	**911 (100)**
Missing	0	0	1	0	1	0	0	0	**2**

* H/S: High school.
† M/S: Middle school.

Table 5-10. Frequency (percentage) of the head blows and concussions by the anatomical site of impact

	Group 2: Head blows without concussion				Group 3: Concussion				
Impact site	H/S* male	H/S female	M/S† male	M/S female	H/S male	H/S female	M/S male	M/S female	**Total**
Side of the head	81 (73.6)	31 (68.9)	286 (77.1)	138 (78.0)	27 (73.0)	10 (83.3)	81 (73.0)	28 (63.6)	**682 (75.2)**
Back of the head	11 (10)	3 (6.7)	21 (5.7)	6 (3.4)	5 (13.5)	1 (8.3)	9 (8.1)	4 (9.1)	**60 (6.6)**
Lower jaw	10 (9.1)	8 (17.8)	49 (13.2)	18 (10.2)	1 (2.7)	1 (8.3)	15 (13.5)	8 (18.2)	**110 (12.1)**
Center of the face	8 (7.3)	3 (6.7)	14 (3.8)	13 (7.3)	4 (10.8)	0	6 (5.4)	3 (6.8)	**51 (5.6)**
Top of the head	0	0	1 (0.3)	2 (1.1)	0	0	0	1 (2.3)	**4 (0.4)**
Total events	110 (100)	45 (100)	371 (100)	177 (100)	37 (100)	12 (100)	111 (100)	44 (100)	**907 (100)**
Missing	1	0	3	0	1	1	0	0	**6**

* H/S: High school.
† M/S: Middle school.

Table 5-11. Frequency distribution of study variables

Variable	Valid cases	Missing (percentage)	Total
Dependant	1,999	96 (4.6)	2,095
Group 1*	1,033		
Group 2†	737		
Group 3‡	229		
Independent			
Education level	2,095	0	2,095
Middle school	1,444		
High school	651		
Gender	2,095	0	2,095
Male	1,487		
Female	608		
Weight	2,087	8 (0.4)	2,095
Fin/fly	448		
Bantam/feather	558		
Light/welter	674		
Middle/heavy	407		
Mouthguard use	2,084	11 (0.5)	2,095
Yes	2,053		
No	31		
Age	1,825	270 (12.9)	2,095
11	1		
12	32		
13	357		
14	408		
15	466		
16	192		
17	186		
18	177		
19	6		
Weigh loss	1,849	246 (11.7)	2,095
No	1,169		
Yes	680		
Training years	1,841	254 (12.1)	2,095
Less than 1	73		
1-3	315		
3-5	421		
5-8	711		
Over 8	321		
Competition years	1,838	257 (12.3)	2,095
Less than 1	269		
1-3	708		
3-5	616		
5-8	228		
Over 8	17		
Past head blow	1,838	257 (12.3)	2,095
No	532		
Yes	1,306		

Table 5-11. Continued

Variable	Valid cases	Missing (percentage)	Total
Past concussion	1,839	256 (12.2)	2,095
No	1,104		
Yes	735		
Blocking skill use	1,828	267 (12.7)	2,095
No	215		
Yes	1,613		

* Group 1: Those that did not receive head blow.
† Group 2: Those that received head blows that did not result in a concussion.
‡ Group 3: Those that received a head blow resulting in a concussion.

Table 5-12. Crude multinomial logistic models

		Group 3*					Group 2†				
Variable	**Group 1‡ (reference)**	***β***	**S.E.**	**Sig.**	**Exp (*β*)**	**95% CI Exp (*β*)**	***β***	**S.E.**	**Sig.**	**Exp (*β*)**	**95% CI Exp (*β*)**
Education level											
Middle school		0.57	0.16	0.00	1.77	1.29-2.43	0.82	0.11	0.00	2.26	1.83-2.8
High school	Reference										
Gender											
Male		-0.003	0.16	0.98	1	0.72-1.37	-0.14	0.11	0.18	0.87	0.71-1.07
Female	Reference										
Weight											
Fin/fly	Reference										
Bantam/feather		0.48	0.22	0.03	1.61	1.06-2.46	-0.1	0.14	0.52	0.91	0.69-1.2
Light/welter		0.04	0.22	0.86	1.04	0.68-1.59	-0.11	0.13	0.43	0.9	0.69-1.17
Middle/heavy		0.6	0.23	0.01	1.83	1.16-2.89	0.37	0.15	0.01	1.45	1.08-1.94
Mouthguard											
No	Reference										
Yes		-1.86	1.02	0.07	0.16	0.02-1.15	-2.34	0.73	0.00	0.1	0.02-0.41
Age		-0.17	0.05	0.001	0.85	0.77-0.93	-0.14	0.04	0.00	0.87	0.81-0.93
Weigh loss											
No	Reference										
Yes		-0.01	0.15	0.93	0.99	0.73-1.33	0.01	0.11	0.9	1.01	0.81-1.26
Training years		-0.02	0.03	0.5	0.98	0.93-1.04	-0.02	0.02	0.23	0.98	0.94-1.01
Competition years		-0.11	0.04	0.01	0.9	0.83-0.97	-0.09	0.03	0.00	0.91	0.86-0.97
Past head blow											
No	Reference										
Yes		-0.16	0.17	0.33	0.85	0.62-1.18	-0.54	0.12	0.00	0.58	0.46-0.73

Table 5-12. Continued

		Group 3*					Group 2†				
Variable	**Group 1‡ (reference)**	**β**	**S.E.**	**Sig.**	**Exp (β)**	**95% CI Exp (β)**	**β**	**S.E.**	**Sig.**	**Exp (β)**	**95% CI Exp (β)**
Past concussion											
No	Reference										
Yes		0.01	0.15	0.97	1.01	0.75-1.35	-0.1	0.11	0.37	0.9	0.73-1.13
Blocking skill use											
No	Reference										
Yes		-0.59	0.21	0.01	0.55	0.37-0.84	-0.37	0.17	0.03	0.69	0.49-0.96

* Group 3: Those that received a head blow resulting in a concussion.
† Group 2: Those that received head blows that did not result in a concussion.
‡ Group 1: Those that did not receive head blow.

Table 5-13. Multivariable logistic model

		Group 3*					Group 2†				
Variable	**Group 1‡ (reference)**	**β**	**S.E.**	**Sig.**	**Exp (β)**	**95% CI Exp (β)**	**β**	**S.E.**	**Sig.**	**Exp (β)**	**95% CI Exp (β)**
Education level											
Middle school		0.63	0.19	0.001	1.88	1.3-2.7	0.76	0.14	0.00	2.13	1.63-2.79
High school	Reference										
Gender											
Male		-0.12	0.17	0.47	0.89	0.64-1.23	-0.16	0.13	0.2	0.85	0.66-1.09
Female	Reference										
Weight											
Fin/fly	Reference										
Bantam/feather		0.39	0.22	0.08	1.48	0.95-2.29	-0.08	0.16	0.62	0.92	0.67-1.27
Light/welter		-0.11	0.23	0.64	0.9	0.57-1.41	-0.23	0.16	0.15	0.79	0.58-1.08
Middle/heavy		0.41	0.25	0.09	1.51	0.94-2.45	0.23	0.18	0.18	1.26	0.9-1.78
Years of competing taekwondo		-0.05	0.05	0.28	0.95	0.87-1.04	-0.03	0.03	0.41	0.97	0.91-1.04
Past head blow											
No	Reference										
Yes		-0.16	0.17	0.36	0.85	0.61-1.19	-0.53	0.12	0.00	0.59	0.46-0.75
Blocking skill use											
No	Reference										
Yes		-0.59	0.22	0.01	0.55	0.36-0.86	-0.41	0.18	0.02	0.67	0.47-0.94

* Group 3: Those that received a head blow resulting in a concussion.
† Group 2: Those that received head blows that did not result in a concussion.
‡ Group 1: Those that did not receive head blow.

Table 5-14. Final multinomial logistic model

		Group 3*					Group 2†				
Variable	**Group 1‡ (reference)**	***β***	**S.E.**	**Sig.**	**Exp (*β*)**	**95% CI Exp (*β*)**	***β***	**S.E.**	**Sig.**	**Exp (*β*)**	**95% CI Exp (*β*)**
Education level											
Middle school		0.64	0.17	0.00	1.89	1.36-2.63	0.77	0.13	0.00	2.16	1.69-2.77
High school	Reference										
Past head blow											
No	Reference										
Yes		-0.14	0.17	0.39	0.87	0.62-1.2	-0.52	0.12	0.00	0.6	0.47-0.76
Blocking skill use											
No	Reference										
Yes		-0.56	0.22	0.01	0.57	0.37-0.88	-0.41	0.17	0.02	0.67	0.47-0.94

* Group 3: Those that received a head blow resulting in a concussion.
† Group 2: Those that received head blows that did not result in a concussion.
‡ Group 1: Those that did not receive head blow.

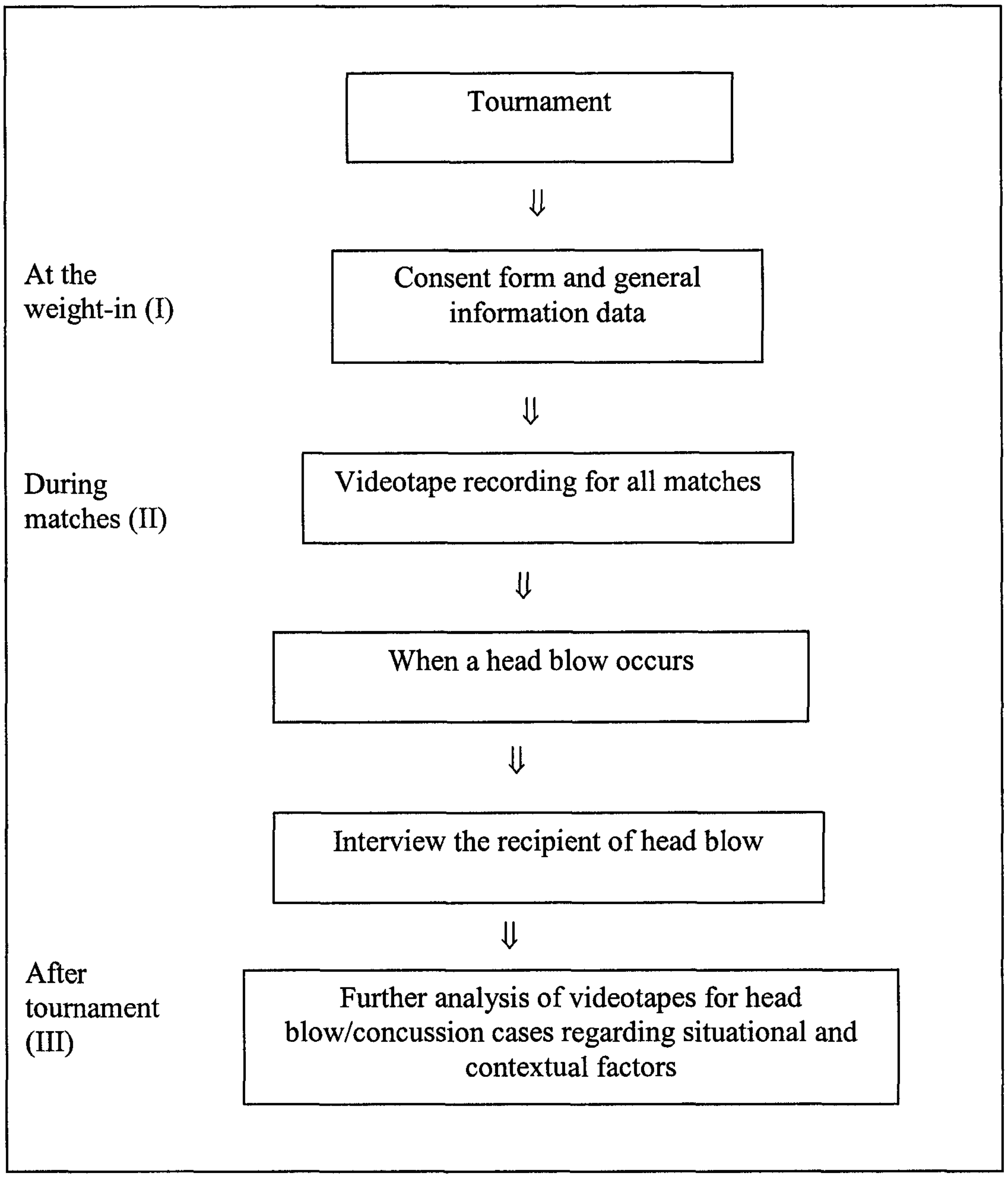

Figure 5-1. Overall research procedure

CHAPTER 6

GENERAL DISCUSSION AND CONCLUSION

Recently, interest in the significance of sport-related concussions is greater than ever due to the potentially high risk of developing long-term cognitive problems from multiple concussions. The research to date, however, is controversial. Some studies reported that concussed athletes experienced diminished memory function, concentration, and reaction time, but the athletes recovered from these deficits in a short time. Also, the recovery time on cognitive functions of the athletes who experienced multiple concussions was longer than that of the athlete who experienced a single concussion. This implies that there is a possibility of cumulative effects of repetitive concussion. On the other hand, some research on chronic traumatic brain injury in soccer has failed to find any evidence of these cumulative deficits. This research suggested that concussion alone may not be enough to cause chronic traumatic brain injury related sequelae. Despite such controversy, concussions can have a significant impact on the continuance of an athletic career, causing temporary suspension of play and even early retirement in some cases.

The purposes of the research detailed in this thesis were to quantify the frequency of injury, more specifically the possibility of concussion following a head blow, and to determine the contexts in which such specific blows are received. In general, the findings of the four studies comprising this dissertation indicate that occurrence of injury, head blow, and concussion is common in competition Taekwondo due to the contact nature of the sport. Also, the incidence rates of injury reported here should be considered minimal due to missing cases brought about by the inclination of some athletes not to interrupt their competition experience with interviews, and research limitations (for example, concussion cases caused by whiplash or a direct contact to other body regions are not included). Nonetheless the concussion rate as defined here in the present study is high. This does not suggest that competition Taekwondo is necessarily a dangerous sport to take part in, but it does suggest that there might be aspects of the sport that could be changed to reduce risks.

The results of the study presented in Chapter 2 showed that approximately 20% of competitors experienced at least one injury due to sparring. From this injury report, the concussion rate was 1.4% of total injuries (8 out of 111 injuries). In Chapter 3, however, a number of significant head blows which could have led to concussion were observed from videotapes. These blows did not always lead to a report of a concussion, suggesting that some concussions may not have been reported in the 1999 data. Thus, results from Chapters 2 and 3 indicated a likelihood of underestimation of incidence of concussion arising from a direct kick to the head/face region. Birrer and Birrer (1983) observed the unreported injury rate in the martial arts. Sixty three percent of injuries sustained in training and competition situations are not reported including concussions and fractures. Also, the findings from the systematic review in Chapter 4 indicated that most incidence reports on concussion in sports tend to be misleading. The actual incidence of concussion may be underestimated due to methodological problems such as absence of an observation, absence of a direct interview, reliance on athletes' self-reports, and the definition of reportable injury/concussion used. Grindel, Lovell, and Collins (2001) suggested that the most accurate method of determining incidence of concussion is direct observation and interview by medical personnel, even though in these cases there may also be a possibility of missing some concussions, especially those that are mild. Using these techniques, the study presented in Chapter 5 revealed that the incidence of concussion following a direct head blow was actually very high in competition Taekwondo.

As expected, there were similar trends with respect to frequency of several variables detailed in Chapter 5 between the head blow recipient group (no concussion reported) and the concussion group. In both groups referee's counts were frequent, though higher in the concussion group. Interestingly, however, many of the head blow recipients, who received a referee's count as a result of kicking power, reported that they did not experience any concussion symptoms at the time of head impact. This can be explained in several ways. First, such a significant head blow does not always result in a concussion. Second, the head blow recipient may have experienced symptoms very briefly, but he or she did not recall or did not consider it to be a significant event, thus he or she did not report the symptoms when asked. Lastly, as Grindel et al. (2001) pointed out, the head blow recipient could have experienced the symptoms, but he or she did not want to report the symptoms for various reasons. A direct and powerful kick to the head would be something that a highly competitive athlete would want to avoid. Thus, to admit receiving such a blow would cause embarrassment. It is likely that the last two assumptions were the main contributors for underestimation/underreporting of incidence of concussion in the past studies, not only in competition Taekwondo, but also in other contact sports. This problem should be considered when conducting research on incidence of concussive brain injury in future studies, and multiple methods should be used (self-reports, observation, videotape, neuropsychological testing) where possible to increase the validity of the interpretation arising from such research.

In American football, several different steps such as rules changes, improved equipment, medical care, and coaching techniques have been suggested and taken to reduce injury. As a result of these changes, the frequency of catastrophic injuries (especially those including the head and neck) seems to have decreased (Mueller, 2001). For example, a significant change to the rules in football included the elimination of head-to-head contact (spearing) that is now illegal. In the case of competition Taekwondo, an ideal strategy for reducing and/or preventing concussion due to a head blow is a rule change which prohibits the head shot. Unfortunately, this would change the sport so significantly that it could destroy the excitement and satisfaction of it entirely. In fact, a new rule in 2002 encourages the head blow by giving even more points to this technique. This will likely lead to an increased frequency of head blow, and subsequently, an increased number of concussions. In light of the importance of the head kick to the sport, other less severe rule changes may be needed. For example, it may be important to put a maximum on the number of powerful kicks received by a competitor (that is, stop the match when this maximum has been reached). This would likely not change the outcome of the fight because the attacker would already have a high score due to the double points gained from these blows. This strategy would also encourage athletes to adopt good defensive strategies to avoid repeated head blows. Alternate strategies may be to award points for successful blocks, and to monitor training periods as well as competition bouts to reduce the possibility of injury there.

In conclusion, athletes, coaches, medical personnel, and governing bodies may need caution following a significant head blow in competition Taekwondo in order to reduce or prevent possible serious injuries related to a head blow. Also, continuous research needs to be done regarding a comparison of concussion incidence before/after rule change and other issues arising from Chapter 5.

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APPENDICES

Appendix A

Faculty of Physical Education and Recreation
University of Alberta

INFORMATION LETTER AND CONSENT FORM

Title of Project: The Injury incidence at the World Taekwondo Championships.

Investigators: Jae Ok, Koh, Ph.D. Student, Faculty of Physical Education & Recreation, # 807, 12020-49 Ave. Edmonton, AB, T6H 2C6. Phone: (780) 439-8538.
Brian Fisher, Ph.D. Associate Professor, Faculty of Physical Education & Recreation, E401 Van Vliet Center, Edmonton, AB, T6G 2H9, (780) 492-8273.
Terry De Freitas, Family Physician in Leduc Medical Art Clinic, 4721-47 Ave. Leduc, AB, T9E 7J4. Phone: (780) 986-1400.

Background: Recreational Taekwondo (TKD) populations, including competitive participants, are growing every year worldwide. TKD is a full contact sport, so engaging in this sport implies injuries occurring, especially during tournaments. There are a few studies of TKD injuries in the recreational level. However, a comprehensive study of elite levels of Taekwondo injuries has not been done. This study will have several advantages. First, a study of TKD injury at elite levels will quantity the frequency, nature, and severity of injuries. Second, all the possible factors -- injury body part, injury type, injury situation, and mechanism will be identified. The study results will be valuable to TKD instructors in terms of safety education and training in the future.

Purpose: You are being asked to participate in a research study. The purpose of this study is to examine the frequency and nature of Taekwondo injuries.

Procedures: After injures occur to a player, a physician will examine his or her injury and project staff will fill out the injury form right after the injury examination at the medical or competition site. The injury examination will be conducted when an injured athlete (or a referee or coach) requests it. Participation in this project will require about 10-15 minutes of your time for the injury examination by the physician. The injury data forms contain the player's gender, weight division, injury situation, different types of kicks, the time of injury occurrence, past injury history, injury site, and injury severity. In addition, if you are injured in the World TKD Championships, the tournament physician and research assistant will complete the injury data forms.

Possible Benefits: There may not be direct benefits to you for being in this study. However, it is expected that once the study is complete, the results will be given to Taekwondo officials and leaders so they may take any action deemed necessary such as improving training methods for avoiding injury situations.

Possible Risks: Risks associated with participation in this study are no greater than participation in the competition.

Confidentiality: Personal records relating to the study will be kept confidential at Dr. De Freitas's office at the Leduc Medical Art Clinic for 5 years after it is published, after which records will be destroyed. All injury data for each participant will be quantified as a total number, and so a participant will not likely be recognized by other participants due to the large number of participants in this study. Any report coming of this research will not give your name or information. Only the study team listed above will have access to your records.

You are free to withdraw from the research study at any time without consequence. If you decline to continue or you withdraw from the study your data will be removed from the study upon your request. Your continuing voluntary participation in TKD will not be affected.

Consent: I acknowledge that I have read this form and I understand the procedures to be performed and the inherent risks and benefits involved form participation in this project. I consent to participate understanding that I may withdraw at any time without consequence. I understand that I will receive a copy of this consent form at the outset of the study if I so wish. To ensure confidentiality, injury data will be stored in a locked limited access room (Dr. De Freitas's office). Normally data are retained for a period of five years, after it is published, after which time it will be destroyed. In addition, all injury data for each participant will be quantified as a total number which may not likely recognized by other participants due to a large number of participants in this study. The University of Alberta creates and collects information for the purposes of research and other activities directly related to its educational and research programs. All participants in research projects are advised that the information they provide, and any other information gathered for research projects, will be protected and used in compliance with Alberta's Freedom of Information and Protection of Privacy Act. I understand that I may make any enquiries concerning any procedure that I do not completely understand. I consent to participate in this research project.

Please contact **Jae Ok, Koh at (780) 439-8538** or **Dr. Terry De Freitas at (780) 986-1400** if you have any questions or concerns. If you have any concerns about any aspect of the study, you may also contact Associate Dean Dr. Jane Watkinson at (780) 492- 5910, Faculty of Physical Education and Recreation.

CONSENT FORM

Title of Project: Injury Incidence at the World Taekwondo Championships.

Investigator: Jae Ok, Koh, Ph.D. Student, Faculty of Physical Education & Recreation, # 807, 12020-49 Ave. Edmonton, AB, T6H 2C6. Phone: (780) 439-8538.
Brian Fisher, Ph.D. Associate Professor, Faculty of Physical Education &Recreation, E401 Van Vliet Center, Edmonton, AB, T6G 2H9, (780) 492-8273.
Terry De Freitas. Family Physician in Leduc Medical Art Clinic, 4721-47 Ave. Leduc, AB, T9E 7J4. Phone: (780) 986-1400.

Please circle **Yes** or **No** in response to each of the following questions:

Do you understand that you have been asked to be in a research study?	**Yes**	**No**
Have you read and received a copy of the attached information sheet?	**Yes**	**No**
Do you understand that there are no known benefits or risks involved in taking part in this study?	**Yes**	**No**
Has the issue of confidentiality been described to you, and do you understand who will have access to the information you provide?	**Yes**	**No**
Have you had an opportunity to ask questions and discuss this study?	**Yes**	**No**
Who explained this study to you?		
I agree to take part in this study:	**Yes**	**No**

Once I get an injury during the tournament and see or require a physician regarding this injury, and agree to participate in this study I will receive a copy of this consent form.

____________________ ____________ ____________________

Signature of Research Participant   Date   Witness

____________________ ____________________

Printed Name   Printed Name

I believe that the person signing this form understands what is involved in the study and voluntarily agrees to participate.

____________________ ____________

Signature of Investigator or Designee   Date

Appendix B

THE WORLD TAEKWONDO CHAMPIONSHIP INJURY STUDY CASE FORM

Faculty of Physical Education and Recreation
University of Alberta

1. Sex:
   1. Male
   2. Female

2. Weight division:
   1. Fin
   2. Fly
   3. Bantam
   4. Feather
   5. Light
   6. Welter
   7. Middle
   8. Heavy

3. During which fight/bout did the injury occur?

1.	1 fight		1.	1st round
2.	2 fight			
3.	3 fight		2.	2nd round
4.	4 fight	============>		
5.	5 fight		3.	3rd round
6.	6 fight			
7.	7 fight			
8.	Other			

4. What activity was involved when you were injured?
   1. Unblocked receiving attack by a kick
   2. Unblocked receiving attack by a punch
   3. Blocked receiving attack by a kick
   4. Blocked receiving attack by a punch
   5. Attacking by a kick
   6. Attacking by a punch
   7. Fall
   8. Fall by an opponent's pushing
   9. Other

5. What kind of techniques caused the injury?
   1. Front snap kick
   2. Roundhouse kick
   3. Side kick
   4. Back kick
   5. Hook kick
   6. Spinning kick
   7. Cutting kick
   8. Other

6. Did the injury happen before (in the last 6 months)?
   1. Yes
   2. No

7. If **#6** is **Yes**, is this the same location?
   1. Yes
   2. No

(Appendix B) continued

DIAGNOSIS (Please print and check the appropriate **BODY PART, CONDITION)**

BODY PART			**CONDITION**	**PRINCIPAL MANAGEMENT OF INJURY**
___ Head	___ Forearm	___Groin	___ Abrasion	______ Surgery
___Face	___Wrist	___Thigh	__Concussion	____ Superficial debridement, minor suturing, dental work, etc.
___ Eye	___ Hand	___ Meniscus	__Contusion	_______ Immobilization (cast, splint, etc).
___ Jaw	___Thumb	___ Knee	__ Laceration	_____ Therapeutic modalities (heat, ultrasound, etc.)
___ Teeth	___ Finger	___ Patella	___ Strain	____ Prescription medication therapy
___ Nose	___Chest	____ Shin	___ Sprain	___ Proprietary management (aspirin, butterfly bandage, etc.)
___Throat	___ Up.Back	___Calf	__ Dislocation	______ Rest
___ Neck	___ Lo.Back	___ Ankle	__ Fracture	
___ Shoulder	___ Co.Sacrum	____ Foot	_ Neurotrauma	
___Clavicle	____ Abdomen	____ Heel	____ Other	
___ Up.arm	____Gonads	___Toes		
___ Elbow	___Genitalia			
___ Spinal Cord	__Hip			

WAS A REFERRAL MADE?	**SEVERITY:**
____ No ____Yes To what health service?	_____ Mild _____ Moderate _____ Severe

OTHER INFORMATION

Appendix C

INFORMATION LETTER
Faculty of Physical Education & Recreation
University of Alberta

Title of Project: Head and Other Injuries in Competition Taekwondo

Investigators: Jae O. Koh, Ph.D. Student, Faculty of Physical Education & Recreation, # 807, 12020-49 Ave. Edmonton, AB, T6H 2C6. Phone: (780) 492-5503.
E. Jane Watkinson, Ph.D. Professor, Faculty of Physical Education & Recreation, E401 Van Vliet Center, Edmonton, AB, T6G 2H9, (780) 492-6583.
J. David Cassidy, Ph.D. Associate Professor of Epidemiology and Medicine, Faculty of Medicine and Dentistry, 3080 RTF, 8303-114st, Edmonton, AB, T6G 2V2, (780) 492-0925.

Background: Recreational Taekwondo (TKD) participants, including competitive participants, are growing every year worldwide. TKD is a full contact sport, so engaging in this sport implies injuries occurring, especially during tournaments. There are a few studies of general injuries in TKD. However, the study of head blows is limited and their consequences in TKD have not been documented. This study will provide useful information. First, a study of TKD injury will quantify the frequency of head blows and concussion. Second, all the possible factors -- injury of body part, injury type, injury situation, mechanism, and technique that caused injury, weight division, and previous injury etc. will be identified. In addition, other body region injuries will be documented. The study results could be valuable to TKD instructors in terms of safety education and training in the future, and to medical personnel in terms of anticipation and treatment of injuries.

Purpose: The purpose of this study is to examine the frequency of head blows and other injuries in TKD competitions and to investigate the frequency of possible brain concussion following head blows.

Procedures: You are being asked to participate in a research study. You will be asked to complete a consent form and a general information form. Second, when/if you are injured, a physician or athletic trainer will examine the injury and complete the required injury assessment at the medical or competition site. Then the physician or project staff will fill out the injury data form for the study. The injury examination will be conducted when an injured athlete (or a referee or coach) requests it. Participation in this project will require about 15 or less minutes of your time for the injury examination by medical personnel. The injury data forms contain the player's gender, weight division, injury situation, different types of kicks, the time of injury occurrence, past injury history, injury site, and injury severity. In addition, if you receive a head blow at the tournament, you will be interviewed by medical personnel or the researcher as to possible effects of the head blow, such as feeling dizzy or dazed etc. after the head blow. This will take approximately 15 minutes. Competitions will be videotaped. In the event of a head blow, the videotape will be used to isolate the head blow and determine the conditions which caused the injury.

Possible Benefits: There may not be direct benefits to you for being in this study. However, once the study is complete, the results will be given to Taekwondo officials and leaders so they may take any action deemed necessary for avoiding injury situations.

Possible Risks: There is no risk involved in participating in this research. You may, however, feel uncomfortable answering questions.

Confidentiality: Videotapes and personal records relating to the study will be kept confidential at Dr. Watkinson's office at the University of Alberta. Normally, information is retained for 5 years after it is published, after which it is destroyed. All injury data for each participant will be quantified as a total number, and so a participant will not likely be recognized by other participants due to the large number of participants in this study. Any report coming of this research will not give your name or information. Only the study team listed above will have access to your records.

You are free to withdraw from the research study at any time without consequence and you may refuse to answer any questions asked of you at any time during your participation. If you decline to continue or you withdraw from the study your data will be removed from the study upon your request. Your continuing voluntary participation in TKD will not be affected.

Additional contacts: "If you have concerns about this study, you may contact the Associate Dean (Research and Graduate Studies) at 492-5910. The Associate Dean has no direct involvement with this project."

CONSENT FORM

Title of Project: Head and Other Injuries in Competition Taekwondo

Investigators: **Jae Ok, Koh**, Ph.D. Student, Faculty of Physical Education & Recreation, # 807, 12020-49 Ave. Edmonton, AB, T6H 2C6. Phone: (780) 492-5503.
E. Jane Watkinson, Ph.D. Professor, Faculty of Physical Education & Recreation, E401 Van Vliet Center, Edmonton, AB, T6G 2H9, (780) 492-6583.
J. David Cassidy, Ph.D. Associate Professor of Epidemiology and Medicine, Faculty of Medicine and Dentistry, 3080 RTF, 8303-114st, Edmonton, AB, T6G 2V2, Phone: (780) 492-0925.

Do you understand that you have been asked to be in a research study?	Yes	No
Have you read and received a copy of the attached Information Sheet?	Yes	No
Do you understand the benefits and risks involved in taking part in this research study?	Yes	No
Have you had an opportunity to ask questions and discuss this study?	Yes	No
Do you understand that you are free to refuse to participate, or to withdraw from the study at any time, without consequence, and that your information will be withdrawn at your request?	Yes	No
Has the issue of confidentiality been explained to you? Do you understand who will have access to your information?	Yes	No

This study was explained to me by: ______________________________

I agree to take part in this study.

_________________________ _______________ _________________________
Signature of Research Participant Date Witness

_________________________ _________________________
Printed Name Printed Name

I believe that the person signing this form understands what is involved in the study and voluntarily agrees to participate.

_________________________ _________________
Signature of Investigator or Designee Date

Appendix D

General Information
Faculty of Physical Education & Recreation
University of Alberta

1. First name____________________ Last name ____________________________

2. Date of birth: ___________________ Phone number:__________________________

3. Name of school or team:____

4. 1) Male 2) Female

5. Weight and weight division: _______________Kg or LB

   1) Fin___ 2) Fly___ 3) Bantam___ 4) Feather___

   5) Light___ 6) Welter___ 7) Middle___ 8) Heavy___

6. Did you lose weight in the 2 weeks before this tournament ? 1) Yes 2) No
   If **yes**, how much?_________Kg or LB

7. How many years of Taekwondo **training experience** do you have? ________Years

8. How many years of **competing Taekwondo** do you have?_______ Months or Years

9. Have you ever had a concussion in the **past 12 months** (see below definition)? 1) Yes 2) No
   What is concussion?
   One received a blow to the head region, or one's head was struck by some object such as ground and kicking/punching techniques during Taekwondo training or tournament, or car accident. One might experience any of the following: feeling dizzy, stun, daze, or seeing stars, or lost consciousness any seconds or minutes.

10. Have you received a kick to the head or face or jaw during training TKD or competing TKD in the **past 12 months?** 1) Yes 2) No

If **yes**, did you feel any of the following symptoms at the time of blow, or after the blow (Please, circle all the symptoms you experienced).

1) Loss of consciousness (knockout)
2) Confusion (e.g., not knowing the time or the place)
3) dizziness
4) Stunned feeling (seeing stars)
5) Headache
6) Blurred vision
7) Tunnel vision
8) Light sensitivity (difficulty in opening eyes for bright light)
9) Ringing in the ear
10) Nausea
11) Vomiting
12) Unusual tiredness
13) Sleeping problem
14) Other (specify)?

11. Do you use a mouth-guard during TKD competition? 1) Yes 2) No

12. Do you use TKD blocking skill(s) against a blow during competition? 1) Yes 2) No

Appendix E

Taekwondo Head Blow Study Case Form
Faculty of Physical Education & Recreation
University of Alberta

Case Number: _____
Time of injury: _____
Blue or Red

I. General information

1. Name:______________________________
2. Time of Injury:____________________________
3. Age:_____________ and Phone number:____________________________
4. Home Address:____
5. Name of school or team:____
6. Gender:
   1. Male
   2. Female
7. Weight and weight division: _____________Kg or LB
   1. Fin
   2. Fly
   3. Bantam
   4. Feather
   5. Light
   6. Welter
   7. Middle
   8. Heavy
8. Did you do weight loss for this tournament? ______Yes ________No
   If yes, how much? _______________Kg or LB
9. How skilled are you at Taekwondo sparring compared to the player you compete against?
   1. Excellent skill
   2. Above average skill
   3. Average skill
   4. Below average skill
   5. Poor skill
10. How many years of experience do you have training Taekwondo?
    ______Years
11. How many years of experience do you have competing Taekwondo?
    _______Years
12. How was your height compared to the opponent when you were injured (head blow)?
    1. Taller than you
    2. About the same as you
    3. Smaller than you

13. During which fight (match) did the injury (head blow)occur?
    1. Single elimination match
    2. Semi-final match
    3. Final match

14. Did you complete all your rounds that when you were injured?
    1. Yes
    2. No

15. The mechanism (cause) of head concussion was
    1. Receiving a blow (direct contact to the body)
    2. Contacting the surface due to falling
    3. Other (be specific)____

16. Have you ever had a head blow (last 12 months)?
    1. Yes
    2. No

17. Did you wear mouth-guard when you were injured?
    1. Yes
    2. No

18. Did you anticipate that you might receive the head attack (blow) from your opponent?
    1. Yes
    2. No

19. Did your coach advise you to protect your head from a possible attack from your opponent during the fight that you were injured?
    1. Yes
    2. No

20. During fights in general, did you usually use blocking skills when you receiving attack?
    1. Yes
    2. No

21. Did you win the match where you received head blow (s)?
    1. Yes
    2. No

II. Head Blow Assessment

The head blow receiver will be asked the followings:

1. Loss of Consciousness: 1. Yes, how long:____________________
   2. No

   If no loss of consciousness, did you feel dazed or stunned or dizzy after head blow?
    1. Yes
    2. No

2. Do you have any symptoms after head blow (or now)? 1. Yes
   2. No

   If Yes, what kinds of symptom do you have now?
    1. Headache
    2. Dizziness
    3. Confusion
    4. Ring in the ear
    5. Nausea

6. Vomiting
7. Vision changes (blurry vision, double vision, tunnel vision)
8. Other ______________________________

3. Diagnosis: Does the head blow receiver concussed as a result of the head blow?
    1. Yes
    2. No

4. Other observations of the head blower (injured athlete):