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Possible Concussions Following Head Blows in the 2001 Canadian National Taekwondo Championships

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Blows to the head and face occur commonly in competition Taekwondo. However, limited research has been done on head blows, particularly those that may result in concussion in competition Taekwondo. Therefore, the purposes of this study were to study the incidence and characteristics of head blow and concussion, and, through visual analysis of competition videotapes, to examine the situational and contextual factors surrounding head blows, with a view to making recommendations that might reduce their frequency. A prospective design with direct observation, interview and videotape recording was used. A total of 212 Canadian competitors (139 males and 73 females) participated in this tournament and ranged in age from 14-24 years. The incidence of head blows and concussions was 273 and 53 per 1,000 athlete-exposures, respectively. None of the head blow recipients lost consciousness following impact to the head. Concussions occur more commonly when competitors adopt a closed sparring stance, and use a roundhouse kick. The most frequent site of impact is the temporal region of the head. In conclusion, the incidence of concussion and head blows is high in competition Taekwondo. This could be decreased with improved skill in blocking kicks to the head and face.

1 Introduction

Olympic/competition Taekwondo is a free-sparring full contact sport. In particular, blows to the head region occur commonly in competition Taekwondo, since the face is a major scoring region. Several studies have reported injuries to the head and face region in Taekwondo tournaments. Among other conditions of injury, there are growing concerns with respect to concussion, since concussion may result in cognitive dysfunction such as memory problems (Master et al., 2000), and its effects may be cumulative (Gaetz et al., 2000; Sortland & Tysvaer, 1989; Yarnell & Lynch, 1973).

Zemper and Pieter (1994) reported that the rate of concussion for Taekwondo is 3 times higher than in college football games, based on number of exposures, and nearly 8 times as high based on time of exposure. In addition, the frequency of concussions seems to have increased since mandatory usage of headgear became required in competition Taekwondo (i.e., since 1985). Cases of concussion reported during World

Taekwondo Championships in 1983 (Siana et al., 1986), 1991 (Pieter & Lufting, 1994), and 1999 (Koh et al., 2001) were one, nine, and eight, respectively. According to these injury reports, wearing headgear in competition Taekwondo reduced the frequency of injuries such as facial bone fracture, but not concussion. One pilot study conducted by McIntosh and McCrory (2001) suggested that headgear does not provide functional protection against concussion in rugby at a junior level. Thus, receiving a head blow may predispose a competitor to potential brain injury regardless of wearing the protective headgear.

Limited research has been done on head blows, particularly those that may result in mild traumatic brain injury in competition Taekwondo. Recently, Koh and Watkinson (2002) analyzed videotapes of head blows in world-class competition Taekwondo They found a number of head blows at a single tournament that had potential for causing mild traumatic brain injury. Also, the results indicated a likelihood of under-reporting of concussion, when data have been acquired only from 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 resulting in misleading incidence of concussion in sports.

Therefore, the purpose of this study is to investigate the incidence and characteristics of head blows and concussions. Also, through visual analysis of competition videotapes, the study is under taken to examine the situational and contextual factors surrounding head blows, with a view to making recommendations that might reduce their frequency.

2 Methods

2.1 Participants and definition of concussion

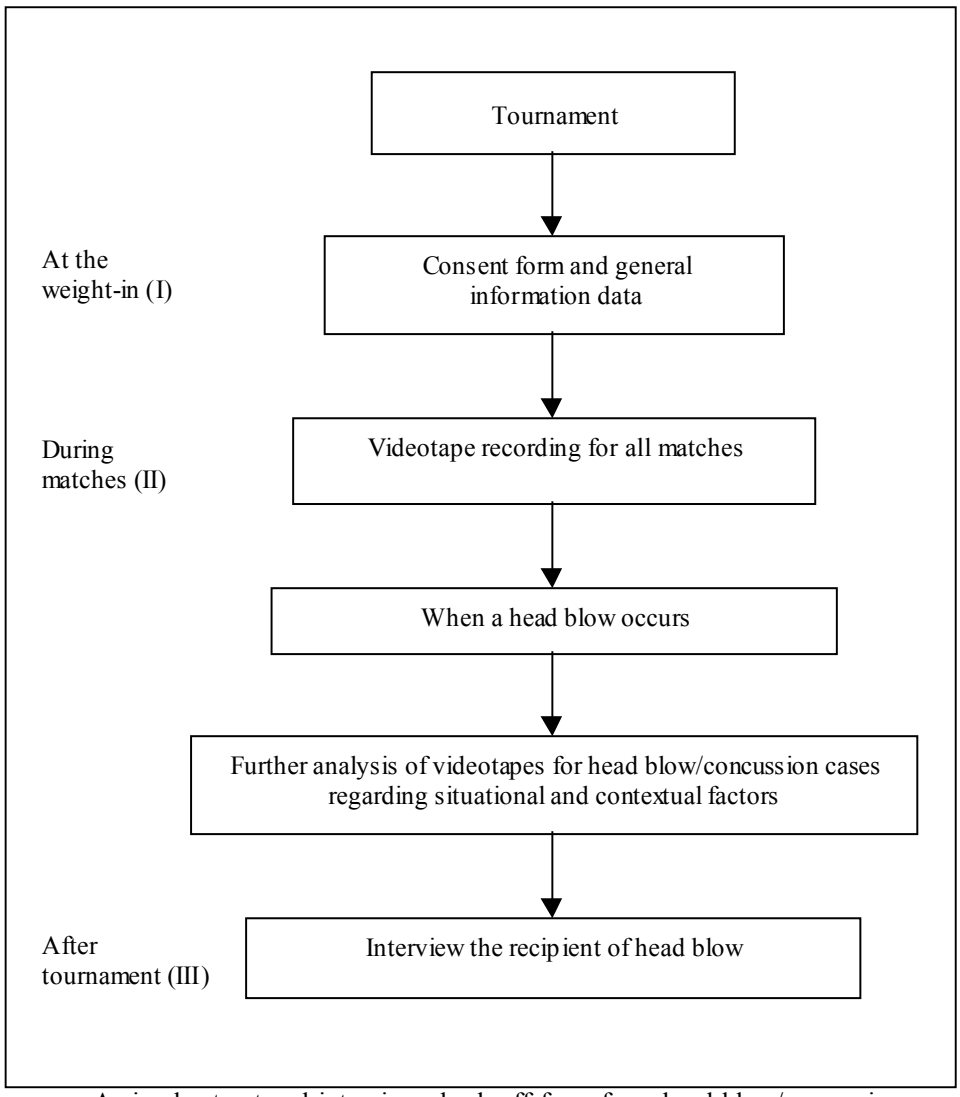
Data were collected at the 2001 Canadian National Championships and Team Trials on June 30 and July 1, 2001 in Edmonton, Canada. A total of 212 competitors (139 males and 73 females) participated in this tournament and ranged in age from 14-24 years.

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 which may induce 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); 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.

2.2 General description of data collection

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

Figure 1



A simple structured interview check-off form for a head blow/concussion case was used. 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, blocking skill and mouth-guard use. In addition, the factors associated with head blows and concussions were recorded and analysed on videotapes

For videotape analyses, tapes of bouts containing all head blows were labelled and stored for later analysis. The head blow video analysis form contained head impact situation/mechanism, including technique that caused any injury or head blow, fighting type/sparring stance, attempted evasive manoeuvres (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 characterised.

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.

2.3 Procedure

2.3.1 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 or she recorded the time of head blow, color 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. In the month following the tournament, the videotapes were reviewed and coded according to procedures developed in a previous study (Koh & Watkinson, 2002).

2.4 Statistical Analysis

In this tournament the single elimination and semifinals were three rounds, lasting two minutes per round, while the final three rounds lasted three 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.

Differences between the head blow without concussion group and the head blow with concussion group were analyzed. In addition, 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 those cases of head blow identified by two independent observers using the head blow criteria mentioned earlier, were used for further analysis. Concussions due to a fall were not included in the videotape analysis. This study was reviewed by the Research Ethics Board of the Faculty of Physical Education and Recreation at the University of Alberta and assessed as meeting the standards of the Canadian Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans.

3 Results

The mean age, training years, and competition years of all respondents were 22.79 (SD 5.3), 9.61 (SD 4.64), and 6.56 (SD 3.83), respectively. A total of 162 (approximately

76% of the total 212 competitors) participants completed the competitors' general information form. One hundred and eight contestants out of 162 respondents lost weight within two weeks prior to the tournament (mean of 1.93 kg, SD 2.06). Sixty competitors out of 162 respondents (37%) had a prior history of receiving a head blow during the previous 12 months. Among these competitors, 22 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, 16 competitors were characterized as having experienced a concussion from participating in Taekwondo during the last 12 months. Of these 16 participants, only eight participants actually reported that they had a concussion. Approximately 51% of participants reported that they use a mouthguard during training and/or competition. Also, 93% of participants reported that they use blocking skills when they receive attacks during sparring.

Table 1 (page 81) shows the frequency of all head blows, head blows that did not result in concussion, concussions, and exposure data. The totals of athlete-exposures and actual minute-exposures were 414 and 2,568, respectively. A total of 11 competitors did not complete all three rounds of the match due to injuries. Overall incidence rates for head blows were 273 [95% CI: 231-319] head blows per 1,000 athlete-exposures and 44 [95% CI: 36-53] head blows per 1,000 minute-exposures. The rates for the concussion were 53 [95% CI: 34-79] concussions per 1,000 athlete-exposures and 9 [95% CI: 5-13] concussions per 1,000 minute-exposures.

Table 2 (page 81) presents the distribution of head blows and concussions by weight division. The highest frequency of head blow occurred in the fin weight class for the males and in the bantam weight class for the females. The highest frequency of concussion occurred in the fly weight class for the males and in the heavy weight class for the females. Most head blows and concussions took place in single elimination (67%), semi-final (21%), and final matches (12%). Only 38% of both head blow and concussed competitors reported the anticipation of a head/face blow from the opponent.

Sixteen concussed competitors reported having one other concussion symptom at the time of interview. Table 3 (page 81)shows the distribution of symptoms experienced by concussed competitors. The most common complaints were dizziness, vision change, and headache. Ten concussed athletes had more than one concussion symptom. There were no facial fractures or skull fractures associated with a head blow.

Table 1:Incidence rates (95% confidence interval) for head blows and concussions in the year 2001 Canadian National Championships and Team Trails

	Males	Females	Total
Number of athletes	139	73	212
Number of matches	136	71	207
A-E	272	142	414
M-E (Actual sparring time)	1680	888	2,568
Head blows	58	55	113
Head blows without concussion	40	44	84
Concussions (number of person)	15	7	22
Head blow rate per 100 athletes	41.73 (33-50)	75.34 (64-85)	53.3 (46-60)
Concussion rate per 100 athletes	10.79 (6-17)	9.59 (4-19)	10.38 (7-15)
Head blow rate per 1,000 A-E	213.24 (166-267)	387.32 (307-473)	272.95 (231-319)
Head blow rate per 1,000 M-E	34.52 (26-44)	61.94 (47-80)	44 (36-53)
Concussion rate per 1,000 A-E	55.15 (31-89)	49.3 (20-99)	53.14 (34-79)
Concussion rate per 1,000 M-E	8.93 (5-15)	7.88 (3-16)	8.57 (5-13)

* 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.

From the videotape screening, a total of 135 head blow scenes including concussions were identified. Of these, 113 head blow scenes were agreed to be significant head blows based on the head blow criteria by two independent observers. The inter observer agreement was 0.82 using the Kappa statistic. Only 113 of the 135 head blow events were used for further analysis.

Table 2: Distribution of head blows and concussions by the weight division

	Frequency of head blow without concussion (%)		Frequency of concussion (%)	
Weight class	Males	Females	Males	Females
Fin	12 (29.3)	8 (18.2)	1 (6.7)	1 (14.3)
Fly	3 (7.3)	3 (6.8)	4 (26.7)	1 (14.3)
Feather	5 (12.2)	11 (25)	3 (20)	0
Bantam	0	14 (31.8)	0	0
Light	7(17.1)	5 (11.4)	1 (6.7)	1 (14.3)
Welter	7 (17.1)	1 (2.3)	1 (6.7)	0
Middle	3(7.3)	2 (4.5)	2 (13.3)	1 (14.3)
Heavy	4 (9.8)	0	3 (20)	3 (42.9)
Missing	0	0	0	0
Total	41 (100)	44 (100)	15 (100)	7 (100)

Table 3: Distribution of symptoms experienced by concussed competitors

Symptoms	Number (percent) of reporting symptoms
Headache	6 (37.5)
Dizziness	10 (62.5)
Confusion	5 (31.3)
Ringing in the ear	1 (6.3)
Nausea	0
Vomiting	0
Vision change	10 (62.5)

Table 4: Distribution of the head blows and concussions by the observed features

	Frequency of head blow without concussion (%)		Frequency of concussion (%)	
Features	Males	Females	Males	Females
LOC*	0	0	0	0
Fall (knocked down/off)	4 (10)	0	6 (42.9)	2 (29)
Gait unsteadiness	12 (30)	6 (13.6)	6 (42.9)	3 (42.8)
No change	24 (60)	38 (86.4)	2 (14.3)	1 (14.3)
Other	0	0	0	1 (14.3)
Missing	1	0	1	0
Total	41 (100)	44 (100)	15 (100)	7 (100)

*LOC: Loss of Consciousness

Table 5: Distribution of the head blows and concussions by total number of head blows

	Frequency of head blow without concussion (%)		Frequency of concussion (%)	
Number of blows	Males	Females	Males	Females
One head blow	26 (65)	20 (45.5)	11 (73.3)	3 (50)
Two head blows	8 (20)	10 (22.7)	4 (26.7)	2 (33.3)
Three head blows	6 (15)	3 (6.8)	0	1 (16.7)
Five head blows	0	5 (11.4)	0	0
Six head blows	0	6 (13.6)	0	0
Missing	1	0	0	1
Total	41 (100)	44 (100)	15 (100)	7 (100)

Tables 4 to 6 show the distribution of head blows and concussions by observed features, total number of head blows, and situations. Based on both videotape and tournament observation, it appeared that none of the head blow recipients lost consciousness following impact to the head. A total of four competitors were knocked

Table 6: Distribution of head blows and concussions by the situation

	Frequency of head blow without concussion (%)		Frequency of concussion (%)	
Situation	Males	Females	Males	Females
Offensive (by counter attack)	19 (47.5)	22 (50)	3 (21.4)	2 (29.6)
Defensive	1 (2.5)	6 (13.6)	3 (21.4)	0
No action	20 (50)	16 (36.4)	8 (57.1)	4 (57.1)
Other	0	0	0	1 (14.3)*
Missing	1	0	1	0
Total	41 (100)	44 (100)	15 (100)	7 (100)

*: The concussion occurred due to a fall.

down and 18 incidents of gait unsteadiness were observed after head blow amongst the athletes who received a head blow that did not result in a concussion. However, there were no other apparent physical changes observed from the concussed competitors post head blow. Overall, 42 competitors received more than one significant head blow in the tournament (Table 4; 5). One athlete had a concussion due to a fall during sparring.

Overall, there were 46 head blows including concussions sustained by an opponent's counter attack (Table 6). The rest of the 48 head blows, including concussions, involved no reaction to a head strike. In all head blow recipients, we observed only one athlete attempting to use a blocking skill, though this was unsuccessful.

Tables 7 to 9 present the frequency of head blows with and without concussion by: kicking techniques, sparring stance, and anatomical site of the head blow impact. Overall, the most common situation of a concussion was when the attacker was situated in closed sparring stance (48%), and with a roundhouse kick (43%). The most frequent anatomical site of head impact was the side of the head (temporal region, approximately 79%) in overall head blows with and without concussion (Table 9).

A total of 24 referee's counts were called among all head blows, including concussions. Of these, 12 referee counts were called among the head blow recipients without concussion (the referee's count 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 powerful technique having been delivered).

The frequency of head blows with and without concussion occurring when the attacker's heights were similar was 47%, followed by taller in 36%, and shorter in 17%. Among the concussed athletes, 77% lost the match and 23% won the match. Among the recipients of a head blow without concussion 85% lost the match and 15% won the match.

4 Discussion

The findings from the present study are significant in terms of identifying the incidence of potential 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

Table 7: Distribution of head blows and concussions by the kicking techniques

	Frequency of head blow without concussion (%)		Frequency of concussion (%)	
Techniques	Males	Females	Males	Females
Axe kick	17 (42.5)	25 (56.8)	4 (28.6)	2 (28.6)
Roundhouse kick	14 (35)	16 (36.4)	6 (42.9)	3 (42.9)
Spinning kick (360)	7 (17.5)	2 (4.5)	2 (14.3)	1 (14.3)
Back kick	2 (5)	1 (2.3)	2 (14.3)	0
Other	0	0	0	1 (14.3)*
Missing	1	0	1	0
Total	41 (100)	44 (100)	15 (100)	7 (100)

*: The concussion occurred due to a fall

other studies where only self-reports were used. Also, follow-up analyses of videotape recording for all fights suggest under-reporting of possible injury cases by observers and competitors. 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.

From the year 2001 Taekwondo Canadian National Championships and Team Trials, approximately ten of every 100 participants is likely to experience an impact to the head that leads to feeling dazed or stunned, and may be accompanied by other symptoms such as headache or dizziness. Based on our case definition of concussion, 22 concussions occurred due to a direct kick to the head, while one was due to a fall. Compared to other published reports on the incidence of concussion in this sport (Pieter & Zemper, 1999; 1998; Koh et al., 2001), the present research shows the highest incidence of concussion. However, when compared to our previous study (Koh & Watkinson, 2002) on the frequency of head blows, the current study shows a lower frequency of head blows (273 head blows versus 365 head blows per 1,000 A-E). However, the frequency in this study was more than our previous study (Koh & Watkinson, 2002) 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.

However, the present study shows a higher frequency of head blows (273 head blows versus 226 head blows per 1,000 A-E) when compared with similar research on incidence of concussion in Korean Taekwondo competition (Koh, 2002, thesis). The reason for this discrepancy is probably different exposure times for each study (1.30 minutes versus 2 minutes versus 3 minutes for each round). In addition, the results of

Table 8: Distribution of the head blows and concussions by the sparring stance

	Frequency of head blow without concussion (%)		Frequency of concussion (%)	
Stance	Males	Females	Males	Females
Closed stance	14 (35)	15 (34.1)	5 (35.7)	5 (71.4)
Open stance	12 (30)	11 (25)	5 (35.7)	1 (14.3)
Clinched stance	13 (32.5)	16 (36.4)	3 (21.4)	0
Other	1 (2.5)	2 (4.5)	1 (7.1)	1 (14.3)*
Missing	1	0	1	0
Total	41 (100)	44 (100)	15 (100)	7 (100)

*: The concussion occurred due to a fall.

incidence rates of concussion for the two studies (i.e., Canadian versus Korean) are similar (50 versus 53 concussions per 1,000 A-E).

When compared with other contact/collision sports (Koh, Cassidy & Watkinson, in press), these competition Taekwondo results present the highest incidence rate for concussion. Since the object of the fight is to contact the head zone, this is not surprising, but there are other possible reasons for this higher incidence, including more accurate methods of data collection here and the different definitions of concussion or injury used. Furthermore there is an indication that there may be under-reporting or under-estimation of the incidence of concussion in previous studies. Koh and Watkinson (2002) 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 actually recognized that they had experienced a 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 explanation of our high rate of concussion is that the current study used "case finding" and our definition of concussion is very "liberal".

Approximately 33% 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. To verify the effects of multiple head blows, further research is necessary in competition Taekwondo.

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

Table 9: Distribution of the head blows and concussions by the anatomical site of impact

	Frequency of head blow without concussion (%)		Frequency of concussion (%)	
Impact site	Males	Females	Males	Females
Side of head/face	32 (80)	38 (86.4)	5 (35.7)	6 (85.7)
Back of head	2 (5)	0	1 (7.1)	1 (14.3)*
Center of face	0	3 (6.8)	4 (28.6)	0
Lower jaw	6 (15)	3 (6.8)	4 (28.6)	0
Missing	1	0	1	0
Total	41 (100)	44 (100)	15 (100)	7 (100)

*: The concussion occurred due to a fall.

(1999), approximately 20% of athletes experience sport related headaches unrelated to concussion.

The types of kick that most commonly caused a concussion were the roundhouse kick (43%), followed by the axe kick (29%), the 360 spinning kick (14%), and the back kick (10%). Similar results were found in previous studies (Koh et al., 2001; Koh, 2002 thesis). Another study conducted by Pieter et al. (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.

We have scrutinized the situation leading up to head blows and concussions. Overall 44% of head blow and concussion 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 injury from the counter attack, the referee's role in discouraging such action presents one option (i.e., according to competition rules involving cases of avoiding the match [revised in 2001], " the penalty shall be given to the one more defensive [which means the counter attacker] and [who] steps back more frequently"). Put differently, the referee should favour attacks over counter attacks.

When the combatants are in the closed sparring stance, the highest frequency of head blows and concussions occurred, followed by the clinched sparring stance. Koh and Watkinson (2002) and Koh (2002, thesis) found similar results. As we indicated in the previous study, the closed sparring stance limits visual and physical access to the torso target areas, but not to the face and head region. This is similar in the clinched sparring stance. 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.

Among the total head blows presented in this study, including concussions, 99% of cases did not involve attempting or preparing evasive manoeuvres at the time of head impact. This indicates that the majority of athletes were not trained to block effectively, particularly against a kick to the head. According to Koh (2002 thesis), the competitors

who were using 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.

Although this research is one of the primary studies 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 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.

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 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 centre 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 conclusion, the incidence of head blow and concussion is high in competition Taekwondo. To prevent or reduce the incidence of concussion in competition Taekwondo, updated safety education, including a complete understanding of concussions for athletes, coaches, and referees; rigorous enforcement of the competition rules by the referee; development of various training programs, especially blocking skills; 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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