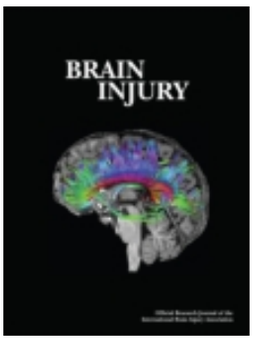

Brain Injury

ISSN: 0269-9052 (Print) 1362-301X (Online) Journal homepage: http://www.tandfonline.com/loi/ibij20

Video analysis of head blows leading to concussion in competition Taekwondo

Jae O. Koh, E. Jane Watkinson & Yong-Jin Yoon

To cite this article: Jae O. Koh, E. Jane Watkinson & Yong-Jin Yoon (2004) Video analysis of head blows leading to concussion in competition Taekwondo, Brain Injury, 18:12, 1287-1296, DOI: 10.1080/02699050410001719907

To link to this article: http://dx.doi.org/10.1080/02699050410001719907

Published online: 03 Jul 2009.

BRAIN INJURY, VOL. 18, NO. 12 (DECEMBER 2004), 1287–1296

Video analysis of head blows leading to concussion in competition Taekwondo

JAE O. KOH†, E. JANE WATKINSON‡ and YONG-JIN YOON†

† Department of Sports & Leisure Studies, Yonsei University, Seoul, South Korea
‡ Faculty of Physical Education and Recreation, University of Alberta, Edmonton, Alberta, Canada

(*Received 4 October 2003; accepted 29 April 2004*)

Primary objectives: To analyse the situational and contextual factors surrounding concussions and head blows in Taekwondo.
Methods and procedures: Prospective design. Direct observation, subject interview and videotape recording used. A total of 2328 competitors participated in the 2001 tournament, South Korea. All matches were recorded on videotape. All recipients of head blows were interviewed by athletic therapists and the researcher immediately after the match. The videotapes of concussions and head blows were analysed.
Results: A total of 1009 head blows including concussions were analysed. Head blows and concussions were most evident when the attacker was situated in a closed stance and received a single roundhouse kick. The most frequent anatomical site of the head impact was the temporal region.
Conclusions: The frequency of head blows and concussions is high in Taekwondo. Development of blocking skills, safety education, rigorous enforcement of the competition rules and improvement of head-gear are recommended.

Introduction

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. In general, the mechanism of concussion is caused by acceleration (a roundhouse kick† or spinning kick‡ in Taekwondo) or deceleration forces (due to falling) or both. Giza and Hovda [1] have reviewed pathophysiologic processes and neurometabolic changes of concussion. They indicate that physiochemical abnormalities associated with loss of consciousness

Correspondence to: Dr Jae O. Koh, Department of Sports & Leisure Studies, 134 Shinchon-dong, Seodaemun-gu, Yonsei University, Seoul 120-749, South Korea. e-mail: kohjaeok@hotmail.com

† The leg is raised through flexion at the hip and knee, force is generated from extension at the knee and also from the body rotation, such that the foot hits the target laterally. The kick is used for attacking the face, trunk or the sides.

‡ The rotation is the other way such that the leg is abducted and flexed, then force is generated through extension at the knee and also from the body rotation. The kick is used for attacking the face.

Brain Injury ISSN 0269–9052 print/ISSN 1362–301X online
http://www.tandf.co.uk/journals
DOI: 10.1080/02699050410001719907

after concussions include hypermetabolism due to the loss of metabolic autoregulation, alterations in the blood–brain barrier, increases in concentrations of acetylcholine, potassium, excitatory amino acids and calcium and reductions in magnesium. These changes and alterations may result in progressive secondary injury to viable brain tissue.

Occurrence of injury is common in competition Taekwondo§ and, because the face is a major scoring area, blows to the head region occur frequently. Several studies have reported injuries to the head and face region in Taekwondo tournaments, including contusions, lacerations, facial fractures, dislocations and concussions. Zemper and Pieter [2] observed that the rate of concussion for Taekwondo is more than two times higher than in college football games, based on number of exposures. Koh *et al.* [3] documented overall injuries in world-class competition Taekwondo. Eight competitors (7.86/1000 athlete-exposures) experienced concussion from this competition. Recently, Koh and Watkinson [4] have analysed 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. They found a significant number of head blows in 19 competitors (365 head blows/1000 athlete-exposures) signifying a high potential for concussion at the tournament. Although they observed a number of head blows during semi and final matches, the frequency of head blows and the resulting frequency of concussion in regular tournament play still needs to be determined. Therefore, the purpose of the present research was to analyse the situational and contextual factors surrounding head blows and concussions in a large tournament, with a goal of identifying strategies that might reduce their frequency.

Methods

Data were collected at the 12th middle and high school Taekwondo tournament on 22–31 July 2001 in Soo-Won, South Korea. A total of 2328 athletes (676 females and 1652 males) from 424 schools participated in the tournament and ranged in age from 11–19 years. There were a total of 4564 athlete-exposures (A–E). During one Taekwondo match, there are two athletes competing at the same time. One athlete-exposure refers to one person being exposed to the risk of sustaining an injury. The tournament was a single elimination competition and competitors wore head and chest protection, arm and shin pads, groin protectors and mouthguards (optional). In this tournament, the single elimination and semi-finals were three rounds, lasting 1.5 minutes per round, while the final three rounds lasted 2 minutes.

From videotape screening, a total of 1111 head blows including concussions were identified. Of these, 1009 were agreed to be 'significant' head blows by two independent observers, based on criteria determined before the match. The inter-observer reliability was 84% using the Kappa statistic [5]. These 1009 of the 1111 head blow events were used for further analysis.

§Competition Taekwondo refers to full contact sparring.

Procedure

A video recorder and an observer observed each match and recorded the occurrence of head blows at each ring. When an observer noted a significant head blow, he or she recorded the time of the blow, the colour of chest gear (e.g. red or blue) and the 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. The videotapes were reviewed and coded at a later time according to the procedure developed in the previous study [4].

The head blow/concussion video analysis form (coding sheet [4]) contained head impact situation/mechanism, including techniques that caused any injury or head blow, fighting type/sparring stance, attempted evasive manoeuvres (e.g. 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.

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' [6]. 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 (post-traumatic 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.

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' (referee's 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.

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.

Results

A total of 1009 head blows were analysed from all bouts at the 2001 competition Taekwondo. Tables 1–3 show the distribution of head blows and concussions by observed features, total number of head blows and situations. Three competitors lost consciousness following impact to the head. The length of time the athletes remained unconscious was less than 1 minute for all three competitors. A total of 58 knocked down/off events and 254 events of gait unsteadiness were observed after a head blow amongst the athletes who received a head blow without sustaining

Table 1. Frequency (%) of the head blows and concussions by the observed features

	Head blows without concussion				Concussion				
	H/S[a] male	H/S female	M/S[b] male	M/S female	H/S male	H/S female	M/S male	M/S female	Total
LOC[c]	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

[a] H/S: High school; [b] M/S: Middle school; [c] LOC: Loss of consciousness.

Table 2. Frequency (%) of the head blows and concussions by total number of head blows

	Head blows without concussion				Concussion				
Number of head blows	H/S[a] male	H/S female	M/S[b] male	M/S female	H/S male	H/S female	M/S male	M/S female	Total
1	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)
2	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)
3	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)
4	0	1 (2.8)	3 (1.1)	1 (0.8)	2 (5.3)	0	0	2 (4.7)	9 (1.2)
6	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[c] (100)	111 (100)	43[c] (100)	736 (100)

[a] H/S: High school; [b] M/S: Middle school; [c] Competitors experienced two concussions from another match.
Note: Number of head blow indicated above only occurred.

Table 3. Frequency (%) of head blows and concussions by the situation

	Head blows without concussion				Concussion				
Situation	H/S[a] male	H/S female	M/S[b] 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

[a] H/S: High school; [b] M/S: Middle school.

a concussion. However, there were no other apparent physical changes observed from the 89 (39%) concussed competitors post-head blow. Overall, 207 (28%) competitors received more than one significant head blow in the tournament (tables 1 and 2).

Overall, there were 402 (44.3%) head blows including concussions sustained by an opponent's counter attack (table 3). The rest of the 338 head blows, including concussions, involved no reaction to a head strike. From all head blow recipients, only 13 (1%) athletes were observed attempting to use blocking skills even though unsuccessful.

Tables 4–6 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 per cent 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 6). 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 centre of the face.

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

† 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 1–10.

Table 4. Frequency (%) of head blows and concussions by the kicking techniques

	Head blows without concussion				Concussion				
Exact kicking technique	H/S[a] male	H/S female	M/S[b] 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

[a] H/S: High school; [b] M/S: Middle school.

The frequency of concussions occurring when the attacker's heights were similar is 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 63 (11%) head blow recipients did not complete all three rounds of the match.

Table 5. Frequency (%) of the head blows and concussions by the sparring stance

	Head blows without concussion				Concussion				
Sparring stance	H/S[a] Male	H/S female	M/S[b] 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

[a] H/S: High school; [b] M/S: Middle school.

Table 6. Frequency (%) of the head blows and concussions by the anatomical site of impact

	Head blows without concussion				Concussion				
Impact site	H/S[a] male	H/S female	M/S[b] 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)
Centre 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

[a] H/S: High school; [b] M/S: Middle school.

Discussion

The findings from the current analysis are significant in terms of analysing the situational and contextual factors surrounding head blows and concussions associated with direct head contact. The present study is the first study to quantify concussions using both direct interviews and videotape recording for all fights. Also, this videotape recording provides an indication that there might be significant under-reporting of possible concussion cases. Furthermore, the results of this video analysis may be useful to athletes, coaches, referees, medical personnel

and manufacturers in terms of reducing head blow and concussion in competition Taekwondo.

The present research shows the highest concussion rate among published studies [7, 8]. However, when compared to a previous study [4] on the frequency of head blows, the current study shows a lower frequency of head blows (365 head blows vs 226 head blows per 1000, A–E). The reason for this discrepancy is probably differences in exposure times between the two tournaments (1.30 minutes vs 3 minutes for each round) and the populations studied. In this case, the competitors were middle and high school students.

From the 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.

The types of kick that most commonly caused a concussion were the roundhouse kick (50%), followed by the axe kick (33%)‡, the back kick (8%) and the spinning kick (6%). The side kick showed the lowest frequency leading to a concussion. Similar results were found in previous studies. Koh *et al.* [3] reported the predominant kick causing concussion was the roundhouse kick. Another study conducted by Pieter *et al.* [9] 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 [10, 11] compared to other Taekwondo kicks and also the most frequently used kick in competition Taekwondo. Additionally, although jumping back and spinning 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.

The situations leading up to head blows have been scrutinized. Forty-four per cent 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 that 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 should be one of discouraging such action (i.e. according to competition rules (revised in 2001), 'the penalty shall be given to the one more defensive (which means the counter attacker) [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. The clinched sparring stance is the second most frequent situation leading to head blows. Koh and Watkinson [4] found that 66% of head blows occurred in the closed sparring stance and 31% in open sparring stance. As indicated in a 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, there is no ability to target a blow to the trunk region, but the head/face region is open. As a result, the most repeatedly used kicking technique was the axe kick, particularly the outside-in axe kick, the primary target of which is the face

‡ The foot is raised above the opponent's head through extension then forced flexion at the hip and is brought down on the head from above. The kick is used for attacking the face.

region. This axe kick is very practical to use when in very closed distances. 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 the cases did not involve attempting or preparing evasive manoeuvres 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 (blocking 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 manoeuvring is that the athletes may not have anticipated the head blow. 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 a clinched sparring position.

It was observed that the predominant site of head impact was the temporal region. Similar results on the frequency of site of impact were found in rugby and Australian Rules Football [12].

In this tournament, only three cases of loss of consciousness were observed, despite a number of significant head blows. This low ratio is likely the result 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 of 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.

With respect to preventive measures for concussion in competition Taekwondo, there are several suggestions based on the findings. First, 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 the clinched sparring position, or during offensive actions. Another possibility is to block a blow coming to the centre of the face by the back kick/straight axe kick or other straight types, by 'ducking', as practiced in boxing. 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, safety education on concussion is needed for athletes and referees. Lastly, improvement of the headgear, particularly to protect the temporal area without interfering with side vision might be helpful.

In summary, a total of 1009 head blows including concussions were analysed. The incidence of concussion and head blow was associated with a 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. 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, the frequency of concussions and head blows in competition Taekwondo is high. To prevent or reduce the frequency of concussion in competition Taekwondo, development of blocking skills, 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 headgear are recommended. Moreover, follow-up research on the incidence of concussion after competition rule changes and the effect of concussion are necessary.

References

1. Giza, C. C. and Hovda, D. A.: The neurometabolic cascade of concussion. *Journal of Athletic Training*, **36**: 228–235, 2001.
2. Zemper, E. D. and Pieter, W.: Cerebral concussions in Taekwondo athletes. In: E. F. Hoerner (editor), *Head and Neck Injuries in Sports* (Philadelphia: American Society for Testing and Materials), pp. 116–123, 1994.
3. Koh, J. O., De Freitas, T. and Watkinson, E. J.: Injuries at the 14th World Taekwondo Championships in 1999. *International Journal of Applied Sports Sciences*, **13**: 33–48, 2001.
4. Koh, J. O. and Watkinson, E. J.: Video analysis of blows to the head and face at the 1999 World Taekwondo Championships. *Journal of Sports Medicine and Physical Fitness*, **42**: 348–353, 2002.
5. Gordis, L.: *Epidemiology*, 2nd edn (New York: W.B. Saunders Company), pp. 77–79, 2000.
6. The Mild Traumatic Brain Injury Committee of the Head Injury Interdisciplinary Special Interest Group of the American Congress of Rehabilitation Medicine: Definition of mild traumatic brain injury. *Journal of Head Trauma and Rehabilitation*, **8**: 86–87, 1993.
7. Pieter, W. and Zemper, E. D.: Incidence of reported cerebral concussion in adult Taekwondo athletes. *Journal of The Royal Society of Health*, **118**: 272–279, 1998.
8. Pieter, W. and Zemper, E. D.: Head and neck injuries in young Taekwondo athletes. *Journal of Sports Medicine and Physical Fitness*, **39**: 147–153, 1999.
9. Pieter, W., van Ryssegem, G., Lufting, R. *et al.*: Injury situation and injury mechanism at the 1993 European taekwondo cup. *Journal of Human Movement Studies*, **28**: 1–24, 1995.
10. Serinal, E. R. and Lieu, D. K.: Thoracic injury potential of basic competition Taekwondo kicks. *Journal of Biomechanics*, **24**: 951–960, 1991.
11. Chuang, T. Y. and Lieu, D. K.: A parametric study of the thoracic injury potential of basic taekwondo kicks. *Journal of Biomechanical Engineering*, **114**: 346–351, 1992.
12. McIntosh, A. S., McCrory, P. and Comerford, J.: The dynamics of concussive head impacts in rugby and Australian Rules Football. *Medicine & Science in Sports and Exercise*, **32**: 1980–1984, 2000.