Transmission of Impact Through the Electronic Body Protector in Taekwondo

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Abstract

This study has been conducted in order to elicit the impact forces transmitted trough Electronic Body Protectors utilized in Taekwondo. By applying a specially designed impact measurement setting, kicks as in real Taekwondo fight were mimicked on mannequins vested or non-vested with Electronic Body Protectors. For different cadet levels, kicks which may bring points were applied. A total of 54 kicks were conducted determining the impact forces absorbed under the Electronic Body Protectors and also on front of the sternum. For measurement of transmitted impact forces, a specially designed sensor system (F-Socket system) was placed between the mannequin and the inner surface of Electronic Body Protectors. The results show that points could be obtained at each cadet level even with low impact forces. The impact of kick transmitted onto the chest increases (24.67%-68.09%) as the cadet level increases. It was also observed that at higher cadet levels transmitted forces were higher depending on the impact level. Thus, it was concluded that the thickness of Electronic Body Protectors must be modified according to the weight divisions utilized in Taekwondo. As it seems to be possible to score points even with low impact forces during Taekwondo competitions, there is no need to use kicks with high impact forces leading to a higher risk of injuries unless athletes seek to disturb the balance of their opponents.

Key word: Taekwondo, Impact force, Electronic Body Protector, Cadet Level

Introduction

Taekwondo (TKD) is a kind of martial art using a high level of nerve-muscle coordination where strong blows in order to stop or deactivate the opponent are necessary (Topal et al., 2011; Koh and Watkinson, 2002; Shirley, 1992), thus having the probability to cause injuries. The multitude of points, as much as 45 %, are scored with the kicks delivered on the chest level (Imamoglu et al., 2010). Although it is necessary to use head, groin, chest, shin, forearm and footdorsum guards during competitions (Tsui and Pain, 2009; Gupta, 2011; Burke et al., 2003), 9.8-15.15% of injuries were detected at chest (Burke et al., 2003; Kazemi, 2009**)** and 7.63% at back (Kazemi, 2009**)**.

The impact forces at delivering kicks were reported at a broad range 382-9015 N (Conkel et al., 1988; Pieter and Pieter, 1995; Chiu et al., 2007; Lee et al., 2008; Falco et al., 2009; O'Sullivan et al., 2009; Pedzich et al., 2006). Impact durations were observed to be diversified as by applying standardized kick 23-26ms (Tsui and Pain, 2009; Estevan et al. 2011) and with sparring partner 40.8- 110 ms (Tsui and Pain, 2009). Although the length and height of EBPs utilized during competitions differ according to the weight of competitor, their thickness do not change, which may lead to a higher rate of incidence of injury at heavy weight competitors in need of a stronger impact force to score points (Gupta, 2011).

The official recognition of TKD at 2000 Sydney Olympic Games brought along the need to a better and more objective judgment of points (Imamoglu et al., 2010). The World Taekwondo Federation (WTF) stipulated the utilization of electronic body protectors (EBPs) with embedded sensors in order to detect points electronically. The system in question is composed of sensors; chest protectors with embedded bluetooth transmitters connecting the sensors with the main system; and the main computer system equipped with a bluetooth receiver. Moreover, the magnetic equipment placed to the back and front of the feet guard of athletes delivering kicks are the main completing component of the system. When the athlete delivers a blow to sensor embedded chest guard area of the opponent with his/her feet having sensors embedded to the front and back of the feet guard with circuit complement, the system detects the scored points taking the velocity and impact force of the kick into account.

Via the software, the kicks above cadet levels in line with the weight division the athlete belongs to are recorded as scored points. This study aims to detect the absorption feature of EBPs by applying standardized kicks within necessary limits to score points.

Material & methods

In this study, WTF approved Daedo brand EBP, feet protector and the related system (EBP-TK STRİKE; Daedo International, Spain; the system approved solely by WTF until January 31, 2013) was utilized. A special testing platform was designed in order to conduct the tests (Picture 1, Picture 2).

Measures

The testing platform was composed of the following components:

1. A high elasticity spring steel with one point fixed and the other (kicking) point embedded with loadcells (Cas Coop, Korea).
2. A prosthetic foot to imitate the kick-delivering athlete's real foot (Eu no: 42; Sach Foot, OttoBock, Germany) equipped with Daedo brand electronic feet protector.
3. A triggering mechanism that fixes the front tension in order the system to conduct similar blows during the repeated evaluations.
4. A mannequin fixed at the top and bottom and wearing a EBP with embedded bluetooth transmitters (Daedo International, Spain).
5. A specially designed sensor system (F-Socket system; Tekscan, Boston, USA) placed between the mannequin and the inner surface of EBP.
6. The F-Socket system sensors (two sensors) were attached to a 8 mm thick (15x22 cm in size) wooden basis (imitation the sternum), covered with 3 mm thick EVA (ottobock, Germany) for the purpose of imitating human soft tissue.

Prosedure

The data collection and evaluation process at the testing platform:

1. Loadcell data (50Hz) were detected via loadcell indicator (Kyowa coorp, PCD 30 A model). The impact force (N) values were obtained through this system.
2. EBP (Daedo International, Spain) data were collected at a special software (Truescore, Daedo International, Spain) via a bluetooth receiver belonging to the system. The data collected through this system were used for determining Cadet levels.
3. Data belonging to the F-Socket system were collected by a special software (F-socket research 6.51; 50Hz). The impact felt at the front part of the chest (wooden basis) and impact time data were obtained through this system.
4. Loadcell and its indicator, EBP and F-Socket systems were activated after they were calibrated and tested in line with instructions provided by the producers.

Speed was fixed at a certain level with a specially designed setup and kicks were delivered with the sole of the foot ((Picture 1, Picture 2) 1).

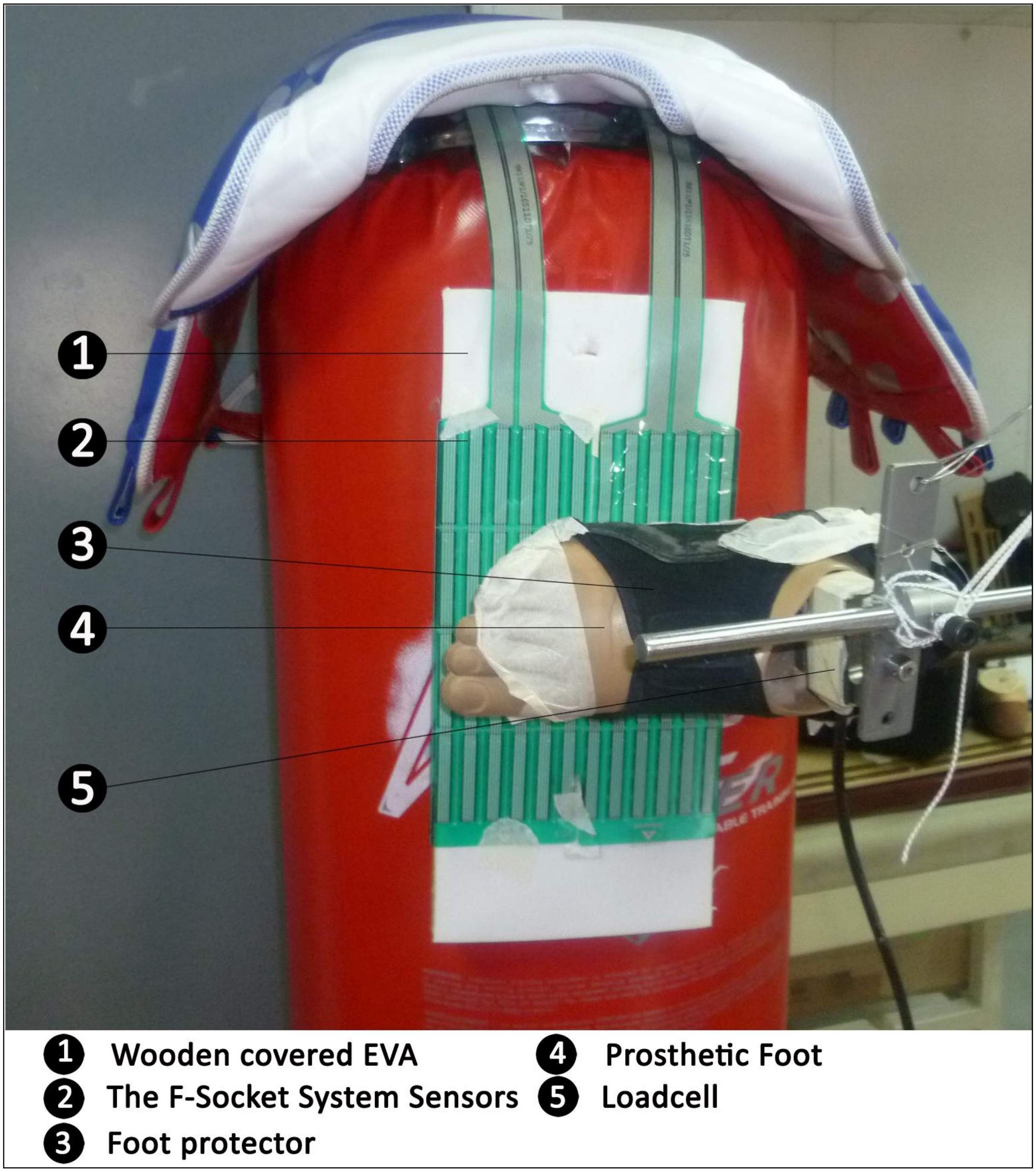
Trial kicks were delivered to the EBP wearing mannequin from a variety of distances through the steel spring system in order to detect the force of the blows that could be scored as points at Cadet levels. With the data collected through this process, it was then possible to realize standardized kicks for each cadet level.

After the completion of pre-trials and evaluations at the prepared setup, direct kicks on the sensors were delivered without using EBP, and the study was completed with blows delivered in order to test the absorbtion of impact forces of EBP at different cadet levels.

Analysis

The impact forces obtained from loadcells through delivered kicks were compared with those obtained through sensors (F-Socket) on the front part of the mannequin (sternum), thus being able to calculate the rate of transmission of impact force on the front part of the mannequin stemming from the loadcell (F-socket /Loadcell X100). Frequency distribution was applied as the statistical method.

Picture 1: Experimental setup A.



Picture 2: Experimental setup B.

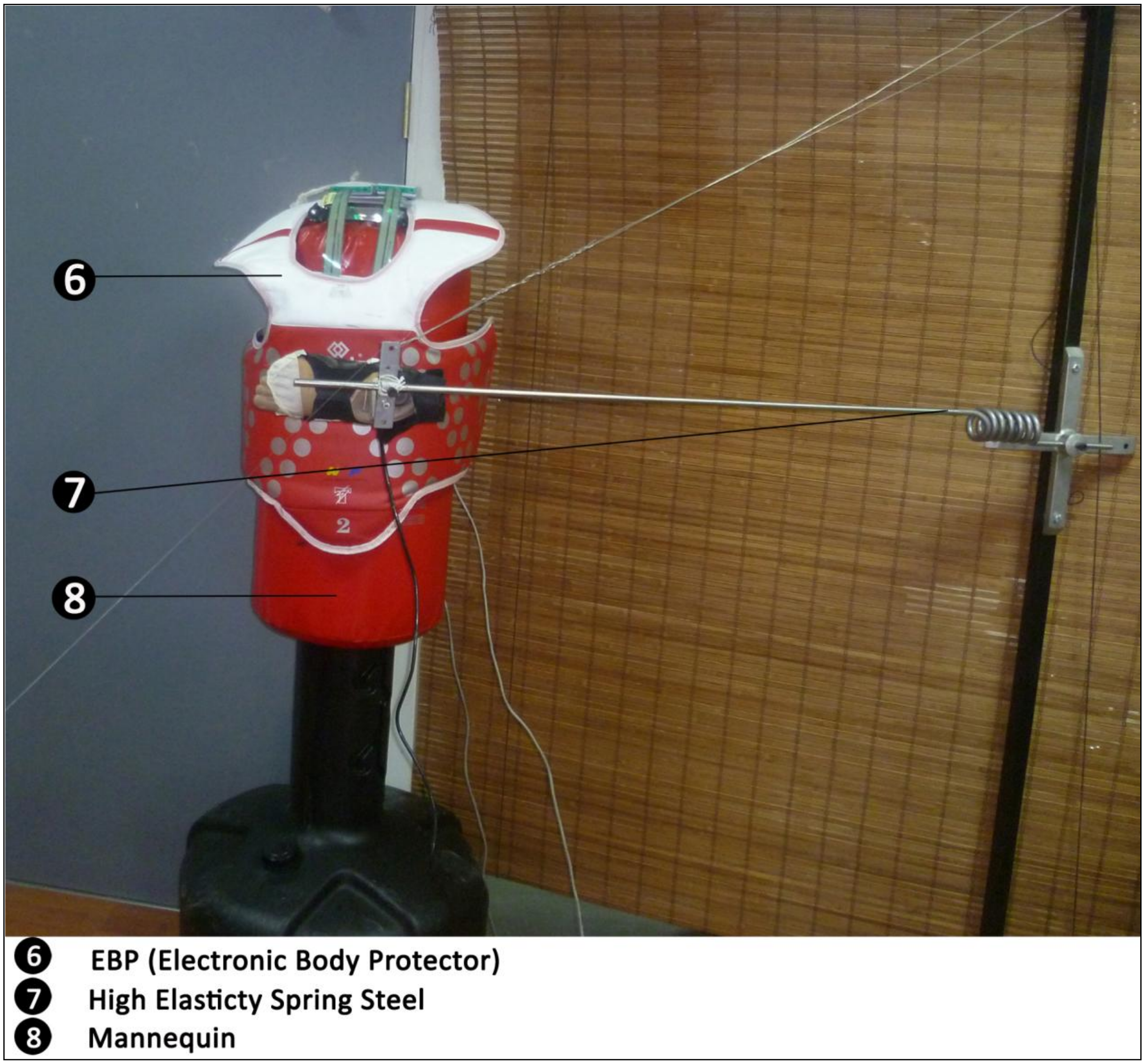


Table 1. Competition category of athletes, cadet levels that may score points, and their EBP sizes.

Male			Female		
Weight division	Cadet level	Size	Weight division	Cadet level	Size
-54kg	24	2	- 46 kg	20	1
54-58 kg	25	2	46-49 kg	22	2
58-63 kg	34	3	59-53 kg	23	2
63-68 kg	35	3	53-57 kg	24	2
68-74 kg	36	4	57-62 kg	32	3
74-80 kg	40	4	62-67 kg	33	3
80-87 kg	41	4	67-73 kg	34	3
87+	42	5	73+	38	4

Results

At the start of the research by delivering 24 kicks, values such as the relation between sensor systems, impact time without EBP etc were collected for the purpose of having preliminary information (Table 2).

Table 2: Loads Without EBP

n	*A- Maximum Impact Force from Loadcell (N)	From F-socket			
		*B- Maximum Impact Force (N)	Impact time (ms)	Impuls (N)	*100 x B/A
24	304.66±136.88	302.65±58.97	20±0.01	8.81±1.85	99.34

It was observed that at kick forces delivered without using EBP, 99.34 % of the impact load was detected by the F-Socked on the front part of the mannequin.

Table 3: Cadet level-Impact Force relation

Cadet Level	Mean+SD	*A- Maximum Impact Force from Loadcell (N)	Under EBP from F-Socket			
			*B- Maximum Impact Force (N)	Impact Time (ms)	Impuls (N)	*100 x B/A
20-21	n=12 20.25±0.45	119.98±21.08	29.61±10.08	25.00±9.05	0.92±0.21	24.67
25-26	n=14 25.50±0.52	144.17±8.38	41.21±13.69	22.9±7.3	1.26±0.32	28.58
35-39	n=13 37.08±1.38	228.60±71.96	110.67±57.92	21.5±5.5	3.23±1.40	48.41
40 +	n=15 43.24±1.18	264.17±77.98	179.89±92.39	24.7±11.9	4.87±2.45	68.09

It was also observed that with kick forces delivered using EBP were transmitted to the F-Sockets on the front part of the mannequin at different rates (% 24.67-68.09%) according to the cadet levels.

Discussion

In this study, the average kicking ranges of the spring to produce score were determined for each cadet level and kicks were delivered within the limits of the range in question (Table 3). For scoring, it was observed that athletes may deliver kicks even at low forces (119-264N). Although the obtained data are nearly identical with those recorded in studies conducted by Conkel et al. (1998), they are still well below those obtained by Pieter and Pieter (1995); Lee et al., (2008); Falco et al., (2009); O'Sullivan et al., (2009) and Pedzich et al., (2006). The reason why impact forces obtained through the conducted researches vary may be due to a variety of factors such as the different methods used to collect data; utilizing different sensors; personal characteristic of athletes delivering kicks; different kicking or training methods (Pedzich et al., 2006; Gupta, 2011). Moreover, the inertia and elasticity of the target is another factor that influences the measurement of impact force (Falco et al., 2009). A heavier, more rigid target, such as a heavy punching bag or padded fixed surface, would allow a subject to record a greater impact force The instrumentation that records has an influence on the value of impact force that is acquired, and thus must be valid and reliable (Pedzich et al., 2006).

Scoring points even through kicks with low impact forces demonstrated with this study elicit the need to discuss the necessity of kicks applied with higher impact forces which may eventually cause increase of injury rates. In addition, although the area where the kicks are delivered during this study may have a certain level of elasticity (flexibility of the mannequin, prosthetic limb etc.) the setup hereby is far from imitating the competition situation. Because while the competition between two opponents continues, the side receiving the kick shall have demonstrate special mimics in order to lessen the impact of the incoming kick. For this reason, the aim while applying kicks with high impact forces is not only to score points but also leave the opponent neutralized.

Tsui and Pain (2009) observed during the research they conducted that transmission level of the impact force (900-1002N) under the impact guard is around 57-74%. In regarding the recording by sensor under guards in this study for 40+ cadet level that may bring along high scores through high impact forces were observed to be close to the values obtained by Tsui and Pain (2009). However, Tsui and Pain (2009) used unstandardize kicks and the number of athletes were inadequate. It is also observed that the details regarding the application of the other standardized method (BSEN- 13277-3-2000) which the researcher informs us that it was used were not included in the study.

It is well known that there is a corelation between the impact force and the weight of the athlete (Falco et al., 2009; Pieter & Pieter 1995; Gupta, 2011; Pedzich et al., 2006; Estevan et al., 2012). It is evident that athletes with heavier weights tend to produce kicks with higher impact forces in order to score points, which inevitably leads to a higher rate of injuries (Gupta, 2011). In this study, it was observed; that athletes at lower cadet levels needed lower impact forces to score points in addition to that proportionally the EBPs absorbed these incoming kicks more. As to the athletes in need of surpassing a higher cadet level, they need to deliver high kicks with high impact forces, which in return shall lower the percentage of impact absorption of EBPs, thus leading the athlete receiving the kick to feel the impact force at a higher level. Thus, it is indicated that wearing the same size (thickness) guard/protector at every competition involving athletes with different cadet levels may increase potential risks. The range between cadet levels determined by WTF for competition weights is quite broad. The impact force increases as cadet level needed to achieve a higher score increases, but EBP features (thickness, material) remains the same, which indicates that the protection capability of EBPs at +40 cadet levels must be questioned.

The material features of the mannequin and EBP must be taken into account because they may effect impact forces by changing the impact duration (Gupta, 2011). Although the impact durations obtained in this study bear similarities to those conducted by Estevan et al (2011) 23-26 ms and Tsui and Pain 24.2 ms in line with the BSEN13277-3-2000 standard, it was established that impact durations are longer in studies conducted by Tsui and Pain (2009) (40.8-49.8 ms) on athletes. The difference in question may stem mainly from the structure of the system that delivers kicks. While a standardized impact system was used in this study, there are a couple of factors leading to a shorter impact duration in other studies such as using real athletes to deliver kicks, thus having kicks with higher impact forces. Also having a fixed mannequin in this study with sensors placed on a wooden plate mounted on the front part decrease the amount of flexibility. The given data are also parallel to the findings indicating that soft material prolongs the impact duration (Gupta 2011).

However, utilizing a prosthetic foot in the specially designed impact setup and conducting the study as close as possible to a real situation by applying EVA covered wooden plate in the front part of the mannequin are the distinctive features of this study. The sensor system detecting the forces reflected on the front part of the mannequin bear similarities with Tsui and Pain’s (2009) study in terms of covering the whole impact area. Falco et al. (2009) stated that he utilized 5 small size sensors (9.53 mm in diameter) in order to collect data. In the study conducted by Falco et al (2009) where sensores were embedded on the mannequin, the exact location of the sensors (whether they were placed on the inner or outer part) were not elaborated in addition to how the impact force were obtained remained obscure. In the same study, sensors did not cover the whole area and the kicks were delivered by athletes instead of a standardized system, all of which aspects are quite the opposite in our study.

As a disadvantage of our study, we may state that although standardized kicks were conducted on a specially designed setup, the rate of standard deviation was observed to be high in the obtained data. The same aspect were observed to be case also for O’Sullivan et al. (2009), Tsui and Pain (2009) and Falco et al. (2009). The other brands were not tested during this study because Daedo is the only brand approved to be used during olympic games by the WTF.

Conclusion

Because it is possible to score points even with low impact forces during TKD self competitions, there is no need to use kicks with high impact forces leading to a higher rate of injuries unless athletes seek to disturb the balance of their opponents. The thickness of EBPs used during competitions has to be rearranged according to weight division.

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References

Burke DT, Barfoot K, Bryant S, Schneider JC, Kim HJ, Levin G. (2003). Effect of implementation of safety measures in Taekwondo competition. *Brit J Sport Med*, 37: 401-4.

Chiu PH, Wang HH, Chen YC. (200). Designing a measurement system for Taekwondo training. XXI ISB Congress, july 1-5, Taipei, Taiwan, *J Biomech*, 40 (suppl.2): S619.

Conkel BS, Braucht J, Wilson W, Pieter W, Taaffe D, Fleck SJ. (1988). Isokinetic torque, kick velocity and force in Taekwondo. *Med Sci Sport Exer*, 20(2): 5.

Electronic body protector and its related system (TK-Strike): until January 31, 2013. Available at: http://www.wtf.org/wtf_eng/site/about_wtf/recognized.html.

Estevan I, Álvarez O, Falco C, Molina-García J. (2011). Impact force and time analysıs influenced by exercutıon distance in a Raundhouse kick to head in Taekwondo. *J Strength Cond Res*, 28 (10): 2851-56.

Estevan I, Falco C, Álvarez O, Molina-García J. (2012). Effect of olympic weight category on performance in the Roundhouse kick to the head in Taekwondo. *J Hum Kinetics*, 31: 37-43.

Falco C, Alvarez O, Castillo I, Estevan I, Martos J, Mugarra F, Iradi A. (2009). Influence of the distance in a roundhouse kick's execution time and impact force in Taekwondo. *J Biomech*, 42: 242–248.

Gupta S. (2011). The Attenuation of strike acceleration with the use of safety equipment in taekwon-do. *Asian J Sport Med*, 2(4): 235-240.

Imamoglu O, Acak M, Bayram L. (2010). Taekwondo Müsabaka Kurallarında Yapılan Bazı Değişikliklerin Müsabakalarda Kullanılan Tekniklere Olan Etkisinin Araştırılması (In Turkish). [Investigation the effect on techniques used in competition of some changes in taekwondo competition] *Spor ve Performans Araştırmaları Dergisi [J Sport Perform Res]*, 1(1): 30-37.

Kazemi M, Chudolinski A, Turgeon M, Simon A, Ho E, Coombe L. (2009). Nine year longituinal retrospective study of taekwondo injuries, *J Can Chiropr Assoc*, 53(4): 272-281.

Koh JO, & Watkinson EJ. (2002). Video analysis of blows to the head and face at the 1999 World Taekwondo Championships. *J Sport Med Phys Fit*, 42 (3): 348–53.

Lee JH, Lee YS, Han KH. (2008). A study on impact analysis of side kick in taekwondo. *Int J Mod Phys B*, 22 (9-11): 1760–1765.

O'Sullivan D, Chung C, Lee K, Kim E, Kang S, Kim T, Shin I. (2009). Measurement and Comparison of Taekwondo and Yongmudo turning kick impact force for two target heights. *J Sport Sci Med*, 8(CSSI III): 13–16.

Pieter F, & Pieter W. (1995). Speed and force in selected Taekwondo techniques. *Biol Sport*, 12 (4): 257–266.

Topal V, Ramazanoglu N, Yılmaz S, Camlıguney A F, Kaya F. (2011). The Effect of Resistance Training with Elastic Bands on Strike Force at Taekwondo. *Am Int J Contemporar Res*, 1(2): 140-144.

Tsui F, & Pain MTG. The effects of testing technique on the performance of chest protectors in taekwon-do. Proceedings of the 33nd Annual Meeting of American Society of Biomechanics (ASB), State College , Agust 26-29, 2009. www.wtf.org. World Taekwondo Federation Competition Rules & Interpretation. In force as of October 4, 2011. Available at: http://www.wtf.org/wtf_eng/site/rules/competition.html.