

## Bivariate analysis of taekwondo actions: The effectiveness of techniques and tactics in an Olympic taekwondo championship

CRISTINA MENESCARDI<sup>1</sup> ✉, ISAAC ESTEVAN<sup>1</sup>, CONCEPCION ROS<sup>2</sup>, ANTONIO HERNÁNDEZ-MENDO<sup>3</sup>, CORAL FALCO<sup>4</sup>

<sup>1</sup>Department of Teaching of Musical, Visual and Corporal Expression, AFIPS Research Group, University of Valencia, Valencia, Spain

<sup>2</sup>Department of Management and Didactics of Physical Activity, GIEPAFS Research Group, Catholic University of Valencia "San Vicente Mártir", Valencia, Spain

<sup>3</sup>Department of Social Psychology, Social Work, Anthropology and East Asian Studies, University of Málaga, Málaga, Spain

<sup>4</sup>Department of Sport, Food and Natural Sciences, Western Norway University of Applied Sciences, Norway

### ABSTRACT

This paper describes the effectiveness of technical-tactical actions performed during a tournament. A total of 14145 actions of the 2012 London Olympic Games were analysed. Differences emerged in the use of tactics, techniques, zones, legs and guard to score. Regarding tactics, anticipatory counterattacks were the most effective for scoring one and three points. Circular techniques were the most effective for scoring one point, linear to score three points, and spin techniques to score two and four points. Actions to the chest results in a score of one to two points and actions to the head in a score of three to four points. The rear leg was more effective in scoring one, two and four points. A close guard was more effective for scoring two points. It is suggested that coaches and athletes pursue training in the aforementioned technical-tactical actions according to the score they desire to obtain during bouts.

**Keywords:** Observational methodology; Performance analysis; Effective patterns; Taekwondo athletes.

#### Cite this article as:

Menescardi, C., Estevan, I., Ros, C., Hernández-Mendo, A., & Falco, C. (2021). Bivariate analysis of taekwondo actions: The effectiveness of techniques and tactics in an Olympic taekwondo championship. *Journal of Human Sport and Exercise*, 16(1), 199-211. doi:<https://doi.org/10.14198/jhse.2021.161.18>

✉ **Corresponding author.** Department of Teaching of Musical, Visual and Corporal Expression, University of Valencia, Av. dels Tarongers, 4. 46022. Valencia. Spain.

E-mail: [cristina.menescardi@uv.es](mailto:cristina.menescardi@uv.es)

Submitted for publication November 13, 2019

Accepted for publication January 27, 2020

Published February 04, 2021 (*in press* February 05, 2020)

JOURNAL OF HUMAN SPORT & EXERCISE ISSN 1988-5202

© Faculty of Education. University of Alicante

doi:10.14198/jhse.2021.161.18

## INTRODUCTION

Taekwondo was a demonstration sport at the 1988 and 1992 Olympics before becoming an official sport eight years later at the 2000 Olympics. Over the years, there has been continuous growth in the number of studies analysing the sport's technical and tactical aspects, such as the types of tactics (Falco et al., 2014; Kassim et al., 2015; Menescardi et al., 2015; Pyciarz, 2011), and techniques (Falco et al., 2012; Matsushigue, Hartmann, & Franchini, 2009; Pyciarz, 2011), height of the target (Falco et al., 2012; Tornello et al., 2014), laterality and kicking leg (Tornello et al., 2014), in addition to the guard position adopted prior to kicking (López-López et al., 2015). For coaches and athletes, it is important to discover the relationship between technical and tactical actions and their effectiveness in order to enhance performance.

Regarding the tactic to score, a greater use of counterattacks has been evidenced since Beijing 2008 in both male and female elite athletes (Kazemi, Perri, & Soave, 2010; Pyciarz, 2011) because it neutralizes the opponent's attack and breaks the rhythm of combat. At Beijing 2008, males and females performed more counterattacks than attacks to score one point, while, in order to score two points, the tendency was inverted, wherein both genders performed more attacks than counterattacks to score (Kazemi et al., 2010). At London 2012, the regulations changed, and athletes were able to obtain one more point by performing kicks with a previous spin (World Taekwondo Federation [WTF], 2012). Therefore, athletes scored two points for spin kicks to the chest, and three or four points for kicks to the head with non-spin and spin techniques, respectively (WTF, 2012). Moreover, the latest changes in the regulations have resulted in greater use of kicks to the head for scoring (Kruszewski et al., 2014; Pyciarz, 2011).

At London 2012, tactical preferences for scoring changed, that is, males performed more attacks than counterattacks to score one and three points, while counterattacks were mostly used to score two and four points. Females performed more effective attacks than counterattacks to score one, two and three points, with one-point actions being the most used to score, followed by three-point actions in both genders. The studies carried out by Kazemi and colleagues (Kazemi et al., 2010, 2014) confirmed the number of effective tactics; however, there is no information about the type of attack or counterattack performed. Knowing this information would allow coaches and athletes to plan and train for tactical sequences of certain techniques in order to win the bout (Menescardi and Estevan, 2017; Menescardi et al., 2016).

Regarding the techniques used to score, due to their speed and accuracy in kicking the opponent's target zone (Pieter and Pieter, 1995; Wąsik, 2010), circular techniques (e.g., Bandal Chagui) are the most used to score (Kassim et al., 2015). However, with the inclusion of electronic chest protectors (called protector scoring system, PSS), the use of linear techniques has increased (Kruszewski et al., 2014; Pyciarz, 2011). As for the height of the target, all studies have shown a major use of techniques in relation to the chest protector rather than to the head due to lesser difficulty being involved (Falco et al., 2012; Tornello et al., 2014). Concerning laterality, techniques are performed with both legs, revealing an athlete's bilateral ability to kick the opponent (Tornello et al., 2014); however, a greater use of the right leg in the rear position is made to score (Tornello et al., 2014), normally, with a close guard (López-López et al., 2015). While relevant studies in the literature reflect the relevance of the aforementioned parameters in competition due to their association with scoring, they do not describe the ways in which to score.

To date, there has been a lack of studies on the Olympic population analysing the actions used to score and their effectiveness. Therefore, the aim of this study was to analyse the effectiveness (i.e., zero points, one point, two points, three points, and four points) of technical and tactical actions performed during an Olympic tournament (i.e., the 2012 Olympic Games) according to the athletes' gender (i.e., males and females).

Descriptive analyses of behavioural interactions contribute to our understanding of human behaviour and behavioural patterns as they occur in natural contexts. It was hypothesized that examining the effectiveness of the actions performed under competition conditions would increase the relevance and applicability of the results for coaches, in turn enabling them to provide training in the most effective actions or counteractions when opponents perform them.

## MATERIALS AND METHODS

### *Participants*

A total of 151 bouts (male,  $n = 75$ ; female,  $n = 76$ ) at an Olympic tournament (London 2012) was recorded and analysed. One male semi-final bout was not carried out due to the injury of one of the athletes. Since the analysed videotapes, on which public behaviour can be observed, are in the public domain, it is not necessary to acquire informed consent from the athletes concerned (American Psychological Association, 2002). The study protocol was approved by the Human Research Ethics Committee at the corresponding author's university.

### *Measures and instruments*

For codifying tactical actions in taekwondo, the taekwondo observational tool (TKDOT) validated by Menescardi et al. (2017) was used (Table 1). HOISAN 1.5.6 software was used for recording and coding the data (Hernández-Mendo et al., 2012), including all of the constituting criteria of the observational tool. With regard to computerized encoding, the data were codified as multi-events as they have been proposed in the context of a multidimensional design.

Table 1. Taekwondo observational tool (TKDOT).

Criterion	Action	Acronym	Description
Tactics	Opening	OPE	Movement to control the distance with the opponent or bridge the gap between both competitors
	Direct attack	DIA	Offensive action with the objective of scoring, ending with an impact on the opponent but without previous movement
	Indirect attack	INA	Offensive action in order to score, ending with an impact on the opponent and with previous movement such as a step, skip, opening, guard change, kicking trajectory modification, etc.
	Anticipatory counterattack	ACA	Action that starts during the opponent's attack with the purpose of scoring. The athlete kicks the attacker during the preparatory phase (guard) and/or initial phase (when the opponent's knee is being raised)
	Simultaneous counterattack	SCA	Action that starts at the same time as the opponent's attack and has a scoring purpose. The athlete kicks at the same time as the opponent. Thus, the counter attacker kicks at the end of the attacker's initial phase (leg raised) or during the impact momentum (impact phase) of the attacker's kick
	Posterior counterattack	PCA	Action that begins after the opponent's attack (during the descending phase, or when attacker's leg touches the ground) with a scoring purpose. Athletes kick at the same time. This action (sometimes) includes a previous backward displacement to dodge the opponent's attack
Techniques	Linear	LIN	The kicking leg is directed toward the front of the opponent's body with a pushing motion in an attempt to kick the opponent with the sole of the foot
	Circular	CIR	The kicking leg is directed toward the opponent's side, with a circular movement in an attempt to kick the opponent with the instep
	Spin	SPI	Action performed with a previous rotation, at least 180° from the initial position, before kicking the opponent

Height target	Head	HEA	Kick to permitted areas of the head
	Chest	CHE	Kick to permitted areas of the chest
Laterality	Right	RIG	Kick performed with the right leg
	Left	LEF	Kick performed with the left leg
Kicking leg	Front	FRO	Kick performed with the leg closest to the opponent
	Rear	REA	Kick performed with leg furthest from the opponent
Guard position	Open	OPE	The front leg of each opponent differs (i.e., one of them has the left leg advanced and the other the right leg)
	Close	CLO	The front leg of both opponents is the same (e.g., both opponents have the left leg advanced)
Score	Zero points	0 point	Action does not impact on the permitted areas, or impacts in these areas but not with enough force to score
	One points	1 point	Score obtained by a valid action performed to the trunk with a linear or circular technique
	Two points	2 points	Score obtained by a valid action performed to the trunk using a spin beforehand
	Three points	3 points	Score obtained by a valid action performed to the head with a linear or circular technique
	Four points	4 points	Score obtained by a valid action performed to the head using a spin beforehand

### **Design and procedure**

The current observational study followed a design characterized as follows (Sánchez-Algarra & Anguera, 2013): point – Olympic championship; nomothetic – 128 athletes; and multidimensional – six technical-tactical parameters: (a) type of tactics, (b) type of technique, (c) height of the target, (d) laterality, (e) kicking leg and (f) guard position. Meanwhile, the level of participation is that of non-participative observation.

A procedure was developed for training observers (Menescardi et al., 2017). Six observers, divided into two groups (A and B), were involved in the reliability analysis of the data. To evaluate the inter-observer reliability, each observer analysed six combats. To evaluate the intra-observer reliability, one of the observers analysed the same six combats twice in a row. Cohen's kappa ( $\kappa$ ) was used to calculate intra- and inter-observer reliability, whose results showed Cohen's  $\kappa$  values above 0.85, showing almost perfect conformity (Landis & Koch, 1977; López-López et al., 2015; Miarka et al., 2015).

### **Statistical analysis**

The effectiveness of each action was determined using contingency tables and Pearson's standard chi-squared ( $\chi^2$ ) in addition to the G-squared test (G2), with a level of acceptance of  $p < .05$ . Two analyses were conducted, one for each gender (males and females). The corrected typified residuals (CTR) were used to indicate whether the difference between the frequency observed and the frequency expected was statistically significant ( $\geq |1.96|$  implies a 95% confidence interval). When  $CTR \geq 1.96$  shows an excitatory relationship, this means that it contributes significantly to the effectiveness of this action in relation to the criterion.

## **RESULTS**

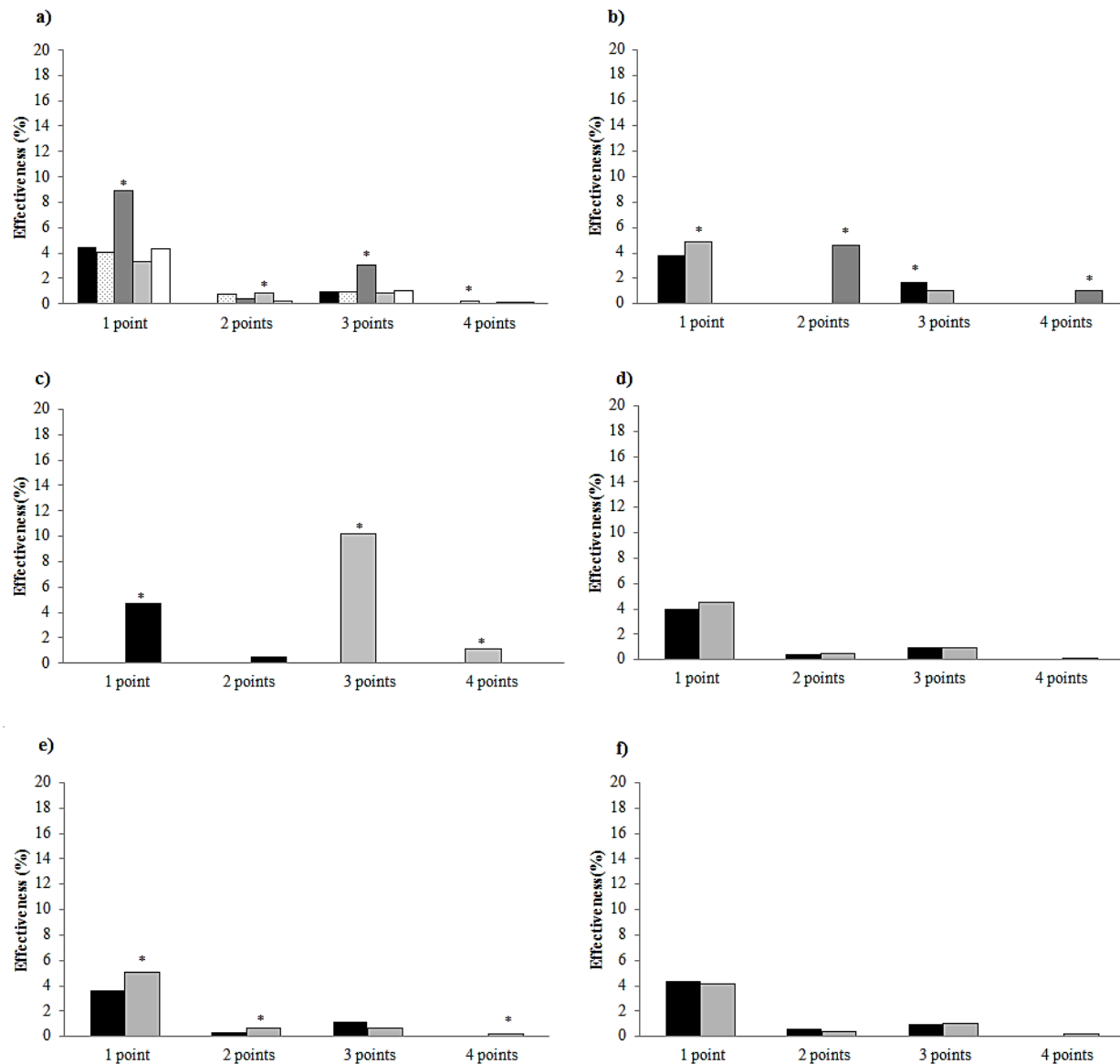
From the 151 bouts analysed, athletes performed 14,145 offensive actions (suitable for scoring), of which males performed 6,824 and female performed 7,321 actions (Table 2). Most of the actions performed were ineffective (13,245 actions [93.64%] scored zero points; specifically, 6,429 were ineffective among males [94.21%] and 6,816 among females [93.10%]). In male athletes (see Figure 1), a significant association was found between effectiveness and tactical actions ( $\chi^2 (16, .05) = 49.01, p < .01$ ;  $G2 = 45.13, p < .01$ ), techniques ( $\chi^2 (8, .05) = 393.25, p < .01$ ;  $G2 = 255.99, p < .01$ ), the height of the target ( $\chi^2 (4, .05) = 732.15,$

$p < .01$ ;  $G2 = 413.65$ ,  $p < .01$ ), and kicking leg ( $\chi^2(4, .05) = 25.39$ ,  $p < .01$ ;  $G2 = 25.75$ ,  $p < .01$ ). No association was found with regard to laterality ( $\chi^2(4, .05) = 2.37$ ,  $p = .65$ ;  $G2 = 2.36$ ,  $p = .65$ ) or guard position ( $\chi^2(4, .05) = 6.63$ ,  $p = .16$ ;  $G2 = 9.08$ ,  $p = .06$ ).

Table 2. Descriptive statistics and corrected typified residuals of technical-tactical variables according to the score in relation to gender.

Criteria		0 points			1 point			2 points			3 points			4 points		
		Fr	%	CT	Fr	%	CT	Fr	%	CT	Fr	%	CT	Fr	%	CT
Male athletes																
Tactics	DIA	2.148	94.4	0.5	102	4.5	0.7	3	0.1	-2.8	22	1.0	-0.1	0	0.0	-1.9
	INA	1.605	94.2	-0.1	68	4.0	-0.6	12	0.7	1.8	15	0.9	-0.5	4	0.2	2.0
	ACA	236	87.7	-4.7	24	8.9	3.9	1	0.4	-0.2	8	3.0	3.4	0	0.0	-0.5
	SCA	1.560	94.9	1.4	55	3.3	-2.1	13	0.8	2.3	13	0.8	-0.9	2	0.1	0.3
	PCA	881	94.4	0.3	40	4.3	0.1	2	0.2	-1.2	9	1.0	-0.1	1	0.1	0.0
Techniques	LIN	1.024	94.5	0.5	41	3.8	-0.8	0	0.0	-2.4	18	1.7	2.5	0	0.0	-1.2
	CIR	4.771	94.1	-0.5	248	4.9	4.6	0	0.0	-9.5	49	1.0	-0.2	0	0.0	-4.5
	SPI	635	94.4	0.1	0	0.0	-5.7	31	4.6	16.9	0	0.0	-2.7	7	1.0	8.0
Height target	HEA	582	88.7	-6.4	0	0.0	-5.7	0	0.0	-1.8	67	10.2	25.2	7	1.1	8.1
	CHE	5.848	94.8	6.4	289	4.7	5.7	31	0.5	1.8	0	0.0	-25.2	0	0.0	-8.1
Laterality	RIG	3.524	94.5	1.0	151	4.0	-0.8	14	0.4	-1.1	38	1.0	0.3	3	0.1	-0.6
	LEF	2.906	93.9	-1.0	138	4.5	0.8	17	0.5	1.1	29	0.9	-0.3	4	0.1	0.6
Kicking leg	FRO	3.649	95.0	3.1	137	3.6	-3.2	10	0.3	-2.7	45	1.2	1.8	1	0.0	-2.2
	REA	2.781	93.2	-3.1	152	5.1	3.2	21	0.7	2.7	22	0.7	-1.8	6	0.2	2.2
Guard	OPE	2.577	94.1	-0.5	120	4.4	0.5	16	0.6	1.3	27	1.0	0.1	0	0.0	-2.2
	CLO	3.853	94.3	0.5	169	4.1	-0.5	15	0.4	-1.3	40	1.0	-0.1	7	0.2	2.2
Female athletes																
Tactics	DIA	2.545	92.5	-1.6	147	5.3	2.8	6	0.2	-2.1	52	1.9	0.3	2	0.1	-1.5
	INA	1.232	93.6	0.8	43	3.3	-2.3	4	0.3	-0.7	35	2.7	2.5	2	0.2	-0.1
	ACA	156	85.7	-4.0	17	9.3	3.2	2	1.1	1.4	7	3.8	2.1	0	0.0	-0.6
	SCA	2.272	93.8	1.7	96	4.0	-1.5	19	0.8	3.3	28	1.2	-3.0	7	0.3	1.9
	PCA	611	94.1	1.1	25	3.9	-0.8	0	0.0	-1.7	12	1.8	0.0	1	0.2	-0.1
Techniques	LIN	1.254	93.4	0.4	40	3.0	-2.9	0	0.0	-2.6	49	3.6	5.5	0	0.0	-1.6
	CIR	5.036	93.1	0.0	288	5.3	5.9	0	0.0	-9.4	85	1.6	-2.8	0	0.0	-5.8
	SPI	526	92.4	-0.6	0	0.0	-5.4	31	5.4	19.2	0	0.0	-3.4	12	2.1	11.9
Kicking zone	HEA	571	79.6	-15.0	0	0.0	-6.1	0	0.0	-1.8	134	18.7	35.5	12	1.7	10.5
	CHE	6.245	94.6	15.0	328	5.0	6.1	31	0.5	1.8	0	0.0	-35.5	0	0.0	-10.5
Laterality	RIG	3.561	92.8	-1.1	175	4.6	0.3	24	0.6	2.8	69	1.8	-0.2	9	0.2	1.6
	LEF	3.255	93.5	1.1	153	4.4	-0.3	7	0.2	-2.8	65	1.9	0.2	3	0.1	-1.6
Kicking leg	FRO	3.955	94.6	5.8	145	3.5	-4.8	4	0.1	-5.0	74	1.8	-0.4	3	0.1	-2.2
	REA	2.861	91.1	-5.8	183	5.8	4.8	27	0.9	5.0	60	1.9	0.4	9	0.3	2.2
Guard	OPE	2.869	93.4	0.9	137	4.5	-0.1	8	0.3	-1.8	53	1.7	-0.6	4	0.1	-0.6
	CLO	3.947	92.9	-0.9	191	4.5	0.1	23	0.5	1.8	81	1.9	0.6	8	0.2	0.6

Note: DIA = Direct attack; INA = Indirect attack; ACA = Anticipatory counterattack; SCA = Simultaneous counterattack; PCA = Posterior counterattack; LIN = linear; CIR = Circular; SPI = With previous spin; HEA = Head; CHE = Chest; RIG = Right; LEF = Left; FRO = Front leg; REA = Rear leg; OPE = Open guard; CLO = Close guard; Fr = Frequency of occurrence; % = percentage of occurrence; CT = corrected typified residuals.

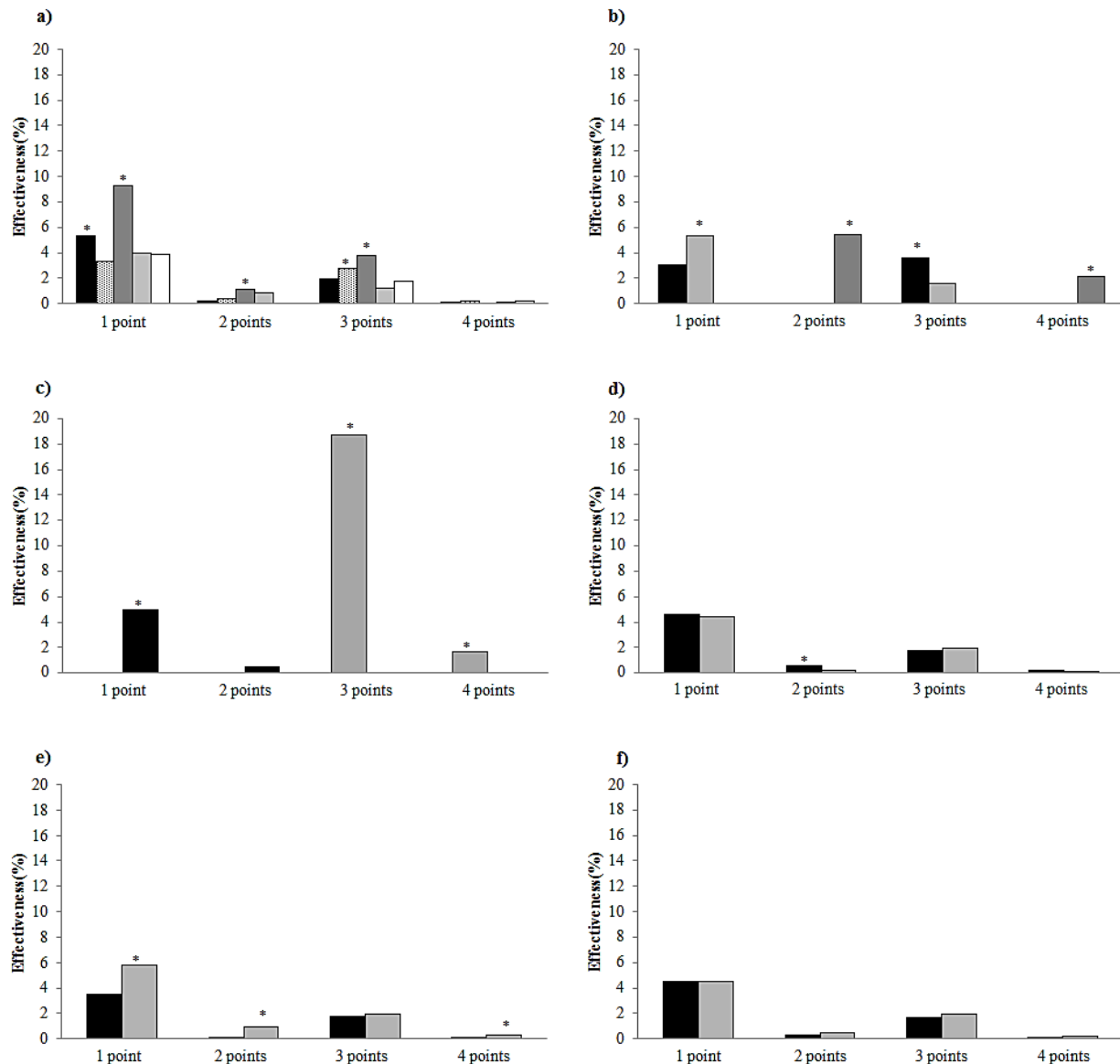


(a) Effectiveness in relation to tactics, the black colour represents direct attacks, the dotted pattern represents indirect attacks, dark grey represents anticipatory counterattacks, light grey represents simultaneous counterattacks and white represents posterior counterattacks; (b) effectiveness in relation to techniques, the black colour represents linear techniques, light grey represents circular techniques and dark grey represents spin techniques; (c) effectiveness in relation to target height, the black colour represents actions to the head and light grey represents actions to the chest; (d) effectiveness in relation to laterality, the black colour represents the right leg and light grey represents the left one; (e) effectiveness in relation to kicking leg, the black colour represents the front leg and light grey represents the rear leg; (f) effectiveness in relation to guard position, the black colour represents a close guard and light grey represents an open guard. \* = significant contribution to the association with the criterion (CTR > 1.96).

Figure 1. Males competitors' effectiveness (%) for each type of score.

As for the tactical actions analysed, anticipatory counterattacks the most effective for scoring one (CTR = 3.9) and three points (CTR = 3.4), simultaneous counterattacks were the most effective for scoring two points (CTR = 2.3), and indirect attacks were the most effective for scoring four points (CTR = 2.0) in male athletes. Concerning the type of technique, circular techniques were the most effective for scoring one point (CTR = 4.6), compared with linear techniques, which were used to score three points (CTR = 2.5), while techniques

with a previous spin were used to score both two and four points (CTR = 16.9 and 8.0, respectively). Actions directed at the chest were used to score one and two points (CTR = 5.7 and 1.8, respectively), while actions to the head scored three and four points (CTR = 25.2 and 8.1, respectively). The rear leg was more effective than the front leg for scoring one, two and four points (CTR = 3.2, 2.7, and 2.2, respectively).



(a) Effectiveness in relation to tactics, the black colour represents direct attacks, the dotted pattern represents indirect attacks, dark grey represents anticipatory counterattacks, light grey represents simultaneous counterattacks and white represents posterior counterattacks; (b) effectiveness in relation to techniques, the black colour represents linear techniques, light grey represents circular techniques and dark grey represents spin techniques; (c) effectiveness in relation to target height, the black colour represents actions to the head and light grey represents actions to the chest; (d) effectiveness in relation to laterality, the black colour represents the right leg and light grey represents the left one; (e) effectiveness in relation to kicking leg, the black colour represents the front leg and light grey represents the rear leg; (f) effectiveness in relation to guard position, the black colour represents a close guard and light grey represents an open guard. \* = significant contribution to the association with the criterion (CTR > 1.96).

Figure 2. Females competitors' effectiveness (%) for each type of score.

With respect to female athletes (see Figure 2), a significant association was found between effectiveness and tactical actions ( $\chi^2(16, .05) = 56.34, p < .01; G2 = 55.17, p < .01$ ), techniques ( $\chi^2(8, .05) = 587.80, p < .01; G2 = 328.18, p < .01$ ), the height of the target ( $\chi^2(4, .05) = 1,399.20, p < .01; G2 = 768.64, p < .01$ ), laterality ( $\chi^2(8, .05) = 10.47, p = .03; G2 = 11.11, p = .03$ ), kicking leg ( $\chi^2(4, .05) = 54.60, p < .01; G2 = 55.98, p < .01$ ), and guard position ( $\chi^2(4, .05) = 4.06, p < .01; G2 = 4.27, p < .01$ ).

That is, most of the actions were ineffective (they scored zero points). From the tactics analysed, direct attacks and anticipatory counterattacks were the most effective for scoring one point (CTR = 2.8 and 3.2, respectively), while anticipatory counterattacks were also used to score three points (CTR = 2.1) in addition to indirect attacks (CTR = 2.5). Simultaneous counterattacks were used to score both two and four points (CTR = 3.3 and 1.9, respectively). As for the type of technique, circular ones were used to score one point (CTR = 5.9), while linear ones were used to score three points (CTR = 5.5) and techniques with a previous spin were used to score both two and four points (CTR = 19.2 and 11.9, respectively). Actions directed at the chest protector were used to score one and two points (CTR = 6.1 and 1.8, respectively), while techniques to the head were used to score three and four points (CTR = 35.5 and 10.5, respectively). Concerning the kicking leg, the rear leg was used to score one, two and four points (CTR = 4.8, 5.0, and 2.2, respectively) while the close guard was more effective for scoring two points (CTR = 1.8).

## DISCUSSION

The aim of this study was to investigate the effectiveness of Olympic athletes' actions (zero points, one point, two points, three points and four points) in terms of the tactic, technique, height of the target, laterality, kicking leg and guard position, according to their gender (male or female), at the 2012 London Olympic Games. To date, this is the first study that has analysed the effectiveness of the actions performed by the taekwondo Olympic population. The results show that most of the actions performed by athletes were ineffective (13,245 out of 14,145 actions scored zero points; 93.64%), which is in line with the findings of Sledziewski et al. (2015), who highlighted the limited effectiveness of actions performed during competitions. This may be explained by the latest regulation changes by which athletes who avoid or delay a match, that is, remain inactive after 15 seconds, are punished (WTF, 2017). For this reason, athletes try to display an active style during openings and tactical actions in order to avoid being punished, rather than with the aim of scoring. As a result, due to this limited effectiveness, it seems important to identify and provide training in the most effective technical and tactical actions under real competition conditions.

The results also show more specific patterns employed for score purposes than in previous studies (Kazemi et al., 2010, 2014), characterized not only by the tactics performed, but also by the techniques, height of the target, laterality, kicking leg or guard. Furthermore, more appropriate actions have been identified for scoring purposes. As the goal of taekwondo athletes is to score more than the opponent throughout the duration of a bout, it is critical to use this time to perform the most effective actions for scoring, instead of losing time and energy performing non-effective actions.

With regard to the types of tactics applied, the results show different patterns applied in order to obtain points among males and females. To score one point, the most effective types of tactics were anticipatory counterattacks (in males 8.9%, in females 9.3%) and direct attacks (in females 5.3%), which supports the findings of González (2011), who analysed the finals of six male elite international championships. These results could be due to the frequent use of direct attacks and the capacity to surprise the opponent with anticipatory counterattacks. These results also show the maintenance of patterns in the course of changes to the regulations in order to score one point. To obtain three points, the results show that males were more



effective with anticipatory counterattacks (3.0%), while females used indirect attacks (2.7%) and anticipatory counterattacks (3.8%). Both actions can be used to surprise the opponent: the time needed to perform an anticipatory counterattack can bewilder the opponent, while the use of an indirect attack can throw the opponent, due to the technical resources needed (e.g., feints) before a kick. In short, the importance of anticipatory counterattacks has been emphasized in previous studies on taekwondo college athletes (Falco et al., 2014; Menescardi et al., 2015), revealing that winners performed more anticipatory counterattacks than non-winners. These results highlight the significance of reacting and anticipating in a very short time to the action of the opponent in achieving success. In terms of the points scored, simultaneous counterattacks were the most effective for scoring two points by males and females (8% for both genders), while, for scoring four points, indirect attacks were used by males (0.2%) and simultaneous counterattacks by females (0.3%). These results reflect the greater effectiveness of both tactics (attack and counter attacks) in scoring two and four points. In line with the present study, Lopez-Lopez et al. (2015) found that actions with a previous spin are followed by another action with a previous spin. Taking into account this scenario, it can be speculated that the counter attacker takes advantage of the spin on the part of the opponent (who performs the attack) (López-López et al., 2015), who is placed in an unfavourable situation because he or she cannot see his or her adversary (Sledziewski et al., 2015); as result, the counter attacker adapts his or her performance to that of the attacker in order to perform a more accurate kick, that is, in the valid areas to score. Thus, it is advisable to provide training in this kind of counterattack because it appears to be effective for the purposes of scoring both two and four points.

Regarding the type of technique, and in line with previous studies (Falco et al., 2012; Matsushigue et al., 2009; Pyciarz, 2011), circular actions were the most performed during this tournament, and the most effective technique for score one point in both genders (males 4.9%, females 5.3%). Circular kicks are performed at high speed and with greater accuracy when they involve the opponent's target zone (Pieter and Pieter, 1995; Wąsik, 2010), enabling athletes to apply major pressure to the impact zone in comparison with linear techniques. With the inclusion of PSS, it is necessary to kick the opponent with speed and potency for the sensor to overpass the umbral level established by the PSS in order to score (Del Vecchio et al., 2011), so it is noteworthy that a greater use of linear techniques was expected after the inclusion of PSS. With the results of the current study in mind, it seems that the use of PSS has not impacted effectiveness according to the type of technique used in competition. Indeed, performing linear actions (e.g., Neryo Chagui) was the most effective technique to the head for scoring three points (1.7% in males, 3.6% in females), which could explain why it is the most suitable technique to kick the opponent's head when close combat occurs.

At the 2012 London Olympic Games, as the use of electronic devices in the head protector was not incorporated into the official competition, it was only necessary to touch the aforementioned zone, rather than to overpass a predetermined umbral level (Moenig, 2017). This fact could also be influential in the relationship between three points and linear techniques, which seem less powerful but speedier than circular techniques or those with a previous spin. That said, the situation here may have changed since the incorporation of electronic head protectors in 2014 (Moenig, 2017). Hence, future studies should analyse the frequency of actions to the head and their effectiveness in order to determine whether patterns have changed over time as a consequence of regulation changes. To obtain two and four points, in our case, athletes performed a technique with a previous spin (to obtain two points: 4.6% and 5.4%, respectively, for males and females; to obtain four points: 1% in males and 2.1% in females), which is in accordance with the regulations for this sport (WTF, 2012).

Regarding the height of the target, to obtain one and two points, athletes (males and females) performed a technique to the chest, while, to obtain three and four points, they performed a technique to the head (WTF,

2012). In line with previous studies (Falco et al., 2012; Tornello et al., 2014), a major use of techniques directed at the chest rather than the head is found. These results may be explained by the lesser difficulty and fewer muscles involved in the movement, leading to less energy being expended during the movement and consequently less fatigue. However, the different levels of effectiveness of those techniques should be noted: one-point actions to the chest (in males: 4.7%; in females: 5.0 %) seemed less effective than three-point actions to the head (in males: 10.2%; in females: 18.7 %). Nevertheless, similar percentages were found for two- and four-point actions for both target heights (two points in both genders: 0.5%; four points: 1.1% in males, and 1.7% in females). As the level of effectiveness, in percentage terms, is greater in comparison to actions to the chest, which is in line with the findings of Estevan and Falco (2013), who compared the mechanical parameters of similar kicks to different target heights, it is advisable to perform a kick to the head instead of the chest, because it produces better scores with similar performance.

In terms of laterality, our results are consistent with previous studies (Falco et al., 2009), which found no significant differences in mechanical variables between right- and left-leg performance. That is, similar frequencies of actions performed with the right and left leg and their effectiveness to score one point (4.0 and 4.5% in males; 4.6 and 4.4% in females), three points (1.0 and 0.9 in males; 1.8 and 1.9% in females), two points (0.4 and 0.5% in males) and four points (0.1% and 0.1% in males; 0.2 and 0.1% in females) were found. Only in female athletes was an association found between the right leg and two-point scores (i.e., kicks with a previous spin to the chest protector). This means that the right leg was more effective for scoring (0.6%) than the left one (0.2%). This result could reflect the major confidence of the athlete in kicking with the dominant leg, as most people are right-handed (González, 2011). However, this represents a very low percentage of actions performed with the right leg. Alternatively, the results of our study mainly highlight taekwondo athletes' bilateral ability to kick. This seems to relate to the fact that athletes can kick their opponent when he or she is unable to guess which side the kick is going to impact.

Concerning the kicking leg, front-leg kicks are usually less powerful than rear-leg kicks, which are used to accumulate points or finish the match with a knockout (Moenig, 2017). Supporting previous findings (Tornello et al., 2014), and given their potentially significant kicking strength (Pieter & Pieter, 1995), the rear leg was more effective for scoring one point (males: 5.1%, females: 5.8%), two points (0.7% and 0.9%, respectively, in males and females) and four points (0.2 % and 0.3% in males and females). In taekwondo, athletes require the ability to maintain dynamic balance when they perform their movements in multidirectional planes (Markovic et al., 2005) and after being kicked. In the literature, the convenience of using linear front-leg kicks (e.g., Moenig, 2017) has been highlighted, due to the opportunity to score relatively faster than when using rear-leg kicks overall during counterattacks. This is based on the necessity to maintain dynamic balance for kicking and provide less time for the opponent to react, even though athletes must maintain a shorter distance in order to kick with the front leg. This reflects the fact that some athletes and coaches will always find weaknesses in any new system and exploit them (Moenig, 2017).

Finally, concerning the guard position, the results show that the type of guard is not related to the type of score, that is, athletes scored one, two, three or four points with either a close or an open guard. This could be a consequence of the guard change being a typical action used in taekwondo to test the opponent's reaction. With regard to the limitations of the current study, on the one hand, in the present study, punches for scoring were not considered in light of the major use of kicking actions (Kazemi et al., 2010; Menescardi et al., 2015; Tornello et al., 2014). On the other hand, attacking and counterattacking tactical actions have been analysed together. It is suggested that future research should not only study the effectiveness in attacks and counterattacks but also include punches as a technique for scoring.

The present study has some practical applications, which can be put into practice. As we found that male and females used different tactics to score, although the type of technique used was similar, it is recommended that male and females train separately in relation to the tactics used (e.g., indirect attacks or simultaneous counterattacks to make kicks to the head with a previous spin technique to score four points), while they can train together in relation to the techniques used. Most of the actions performed were ineffective (scored zero points) and most of the effective actions were one-point actions (actions directed at the chest with a circular or linear technique), in accordance with their major occurrence compared to other techniques. Right and left legs were used indistinctly to kick the opponent, as both legs are, in the main, equally effective and athletes need to train in order defend both sides equally if they are to have a bilateral ability for kicking the opponent.

## CONCLUSIONS

Based on the results of the present study, the following conclusions can be made: 1) To score one point, both male and females performed anticipatory counterattacks and direct attacks (the latter only applied to females), in addition to circular techniques to the chest with the rear leg. 2) To score three points, both males and females used anticipatory counterattacks and indirect attacks (the latter only applied to females), which were performed with linear techniques to the head. 3) To score two points, both males and females performed simultaneous counterattacks, with a previous spin technique, performed with the rear leg, and from a close guard (only in females). 4) Finally, to score four points, male and females performed indirect attacks and simultaneous counterattacks, respectively, with a previous spin to the head.

## AUTHOR CONTRIBUTIONS

CM participated in the study design and data collection, conducted statistical analyses and contributed to the interpretation of the results, drafted the manuscript, and approved the final manuscript as submitted. CF and IE conceived the study, participated in its design and coordination, contributed to video coding, data collection and to the interpretation of results, drafted the manuscript, and approved the final manuscript as submitted. CR and AH-M participated in the study design, contributed to the interpretation of the results, reviewed and provided feedback to the manuscript, and approved the final manuscript as submitted. All authors made substantial contributions to the final manuscript.

## SUPPORTING AGENCIES

This work was supported by the Conselleria d'Educació, Cultura i Esport of the Generalitat Valenciana; under Grant ACIF/2014/268. This study was also supported by one grant (DEP2015-66069-P) from the Department of Research, Development and Innovation of the Spanish Ministry of the Economy.

## DISCLOSURE STATEMENT

We have no conflicts of interest to disclose.

## REFERENCES

- American Psychological Association (2002). Ethical principles of psychologists and code of conduct. *Am Psychol*, 57(12), 1060–1073. <https://doi.org/10.1037/0003-066x.57.12.1060>

- Del Vecchio, F. B., Franchini, E., Del Vecchio, A. H. M., & Pieter, W. (2011). Energy absorbed by electronic body protector from kicks in a taekwondo competition. *Biol Sport*, 28(1), 75-78.
- Estevan, I. & Falco, C. (2013). Mechanical analysis of the roundhouse kick according to height and distance in taekwondo. *Biol Sport*, 30(4), 275-279. <https://doi.org/10.5604/20831862.1077553>
- 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(3), 242-248. <https://doi.org/10.1016/j.jbiomech.2008.10.041>
- Falco, C., Estevan, I., Álvarez, O., Morales-Sánchez, V., & Hernández-Mendo, A. (2014). Tactical analysis of the winners' and non-winners' performances in a Taekwondo University Championship. *Int J Sports Sci Coach*, 9(6), 1407-1416. <https://doi.org/10.1260/1747-9541.9.6.1407>
- Falco, C., Landeo, R., Menescardi, C., Bermejo, J. L., & Estevan, I. (2012). Match analysis in a university taekwondo championship. *Adv Phys Edu*, 2(1), 28-31. <https://doi.org/10.4236/ape.2012.21005>
- González- Prado, C. (2011). Technical-tactical characterization of high-level combat competition (doctoral dissertation). Barcelona: Universitat de Barcelona.
- Hernández-Mendo, A., López-López, J. A., Castellano, J., Morales-Sánchez, V., & Pastrana, J. L. (2012). HOISAN 1.2: Programa informático para uso en Metodología Observacional. *Cuad Psicol Dep*, 12(1), 55-78. <https://doi.org/10.4321/s1578-84232012000100006>
- Kassim, S. F. A. M., Suwarganda, E. K., & Nor, E. N. A. M. (2015). Successful tactics in taekwondo during Sukan Malaysia 2012. *J Hum Sport Exerc*, 10 (Proc2), S723-S730. <https://doi.org/10.14198/jhse.2015.10.proc2.12>
- Kazemi, M., Perri, G., & Soave, D. (2010). A profile of 2008 Olympic Taekwondo competitors. *J Can Chiropr Assoc*, 54(4), 243.
- Kazemi, M., Ong, M., Pacis, A., Tseng, K. (2014). A profile of 2012 Olympic Games Taekwondo Athletes. *J Int Assoc Taekwondo Res*, 1(2), 12-18.
- Kruszewski, A., Kuźmicki, S., Podchul, A., & Kruszewski, M. (2014). Effect of changes in the sports regulations on the fight of taekwondo female players on the example of Beijing Olympic Tournaments 2008 and London 2012. *J Combat Sports Martial Arts*, 5(2), 97-100. <https://doi.org/10.5604/20815735.1141983>
- Landis J. & Koch G. (1977). The measurement of observer agreement for categorical data. *Biometrics*, 33, 159-174. <https://doi.org/10.2307/2529310>
- López-López, J. A., Menescardi, C., Estevan, I., Falcó, C., & Hernández-Mendo, A. (2015). Análisis técnico-táctico en Taekwondo con coordenadas polares a través del software HOISAN. *Cuad Psicol Dep*, 15(1), 131-142. <https://doi.org/10.4321/s1578-84232015000100013>
- Markovic, G, Misigoj-Durakovic, M, & Trninic, S. (2005). Fitness profile of elite Croatian female taekwondo athletes. *Collegium Antropologicum* 29, 93-99.
- Matsushigue, K. A., Hartmann, K., & Franchini, E. (2009). Taekwondo: Physiological responses and match analysis. *J Strength Cond Res*, 23(4), 1112-1117. <https://doi.org/10.1519/jsc.0b013e3181a3c597>
- Menescardi, C., Lopez-Lopez, J. A., Falco, C., Hernandez-Mendo, A., & Estevan, I. (2015). Tactical aspects of a National university Taekwondo championship in relation to round and match outcome. *J Strength Cond Res*, 29(2), 466-471. <https://doi.org/10.1519/jsc.0000000000000645>
- Menescardi, C., Estevan, I., Falco, C., & Hernández-Mendo, A. (2017). Generalizability Theory Applied to Olympic Taekwondo Combats. *Eur J Hum Mov*, 39, 65-81.
- Menescardi, C., & Estevan, I. (2017). Detection of behavioural patterns in Olympic male taekwondo athletes. *J Hum Sport Exerc*, 12(2), 435-445. <https://doi.org/10.14198/jhse.2017.122.20>
- Menescardi, C., Estevan, I., & Falco, C. (2016). Polar coordinates in taekwondo. *Rev Art Marciales Asiáticas*, 11(2s), 4-5. <https://doi.org/10.18002/rama.v11i2s.4167>

- Miarka, B., Branco, B. H., Vecchio, F. B., Camey, S., & Franchini, E. (2015). Development and validation of a time-motion judo combat model based on the Markovian Processes. *Int J Perf Anal Sport*, 15(1), 315–331. <https://doi.org/10.1080/24748668.2015.11868795>
- Moenig, U. (2017). Dominant features and negative trends in the current World Taekwondo Federation (WTF) competition system. *Ido Mov Cult. J Martial Art Anthropol*, 17(3), 56–67.
- Pieter, F., & Pieter, W. (1995). Speed and force in selected taekwondo techniques. *Biol Sport*, 12(4), 257–266.
- Pyciarz, T. (2011). Analysis of sport fight structure in Taekwondo during the Olympics in Beijing in 2008 and Senior World Championships in 2009 in terms of technical skills after regulation and implementation of the electronic system of score recording. *J Combat Sport Martial Art*, 2(2), 109–115.
- Sánchez-Algarra, P., & Anguera, M. T. (2013). Qualitative/quantitative integration in the inductive observational study of interactive behaviour: impact of recording and coding predominating perspectives. *Qual Quant*, 47, 1237–1257. <https://doi.org/10.1007/s11135-012-9764-6>
- Sledziewski, D., Loniewski, M., Kuder, A., Dias, R. A., Ferreira, G., Pena, B., & Sznuchrowski, L. (2015). Fighting profiles in men's taekwondo competition in the under 68 kg category at the Olympic Games in Beijing (2008) and London (2012) - Case studies. *Arch Budo*, 11(1), 1-9.
- Tornello, F., Capranica, L., Minganti, C., Chiodo, S., Condello, G., & Tessitore, A. (2014). Technical-tactical analysis of youth Olympic Taekwondo combat. *J Strength Cond Res*, 28(4), 1151–1157. <https://doi.org/10.1519/jsc.000000000000255>
- Wąsik, J. (2010). The structure of the roundhouse kick on the example of a European Champion of taekwon-do. *Arch Budo*, 6(4), 211–216.
- World Taekwondo Federation (2017). Rules and Regulations. Retrieved from [http://www.wtf.org/wtf\\_eng/site/rules/competition.html](http://www.wtf.org/wtf_eng/site/rules/competition.html)

