Original Article

# Detection of behavioural patterns in Olympic male taekwondo athletes

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**ABSTRACT**

The relationship between athletes' behaviours is relevant for developing defensive and offensive strategies. Traditionally, sequential analysis has been conducted to assess relationships between two behaviours (one considered as focal and the other as conditioned). The aim of the study was to examine Olympic taekwondo athletes' behavioural patterns by conducting sequential analyses of tactical actions in bouts. Seventy-five male matches of the London Olympic Games in 2012 were studied to analyse tactical actions: attack (direct and indirect), counterattack (anticipatory, simultaneous and posterior), defensive (cuts, blocks and dodges), and opening actions. A sequential analysis of 2 lags (i.e., actions) in both prospective and retrospective perspectives were conducted by using five focal behaviours (i.e., those considered as tactical scoring actions: direct and indirect attack, anticipatory, simultaneous and posterior counterattacks). The results showed different tactical sequences according to the type of action considered as focal in the analysis. Specifically, direct attacks and simultaneous counterattacks were the most frequently action used in competition. Sequential analyses confirmed the interchangeable pattern of attacking and counterattacking actions. Those analyses can provide an insight for athletes' patterns and tactical strategy training in taekwondo based on empirical data. **Key words:** TAEKWONDO, SEQUENCES, TACTICS, OLYMPIC ATHLETES

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## INTRODUCTION

Taekwondo is an Olympic combat sport characterized by a continuous tactical movements interchange involving offensive and defensive phases. During bouts, athletes observe the opponent actively (by moving, stepping and performing opening actions) to apply a specific strategy (Ruiz-Sanchis, Ros, & Bastida, 2016). Observational analyses showed that taekwondo athletes try to create and adapt their tactics according to the opponent's one and choose what they consider as high favourable to score and win the bout (Mazlan, Osman, Usman, & Abas, 2007).

Observation analysis in taekwondo has been focused on the frequency of technical-tactical indicators such as the number of kicks (Matsushigue, Hartmann, & Franchini, 2009), the type of techniques used (Tornello et al., 2014), the kicking zone (Falco, Landeo, Menescardi, Bermejo, & Estevan, 2012) or the effectiveness of techniques (González, 2011). However, despite the relationship between athletes' behaviours is relevant for developing defensive and offensive strategies, no study was found that analyses behavioural patterns in order to describe tactical sequences in taekwondo.

To analyse tactical sequences in the sport field (Castellano, Hernández-Mendo, Morales-Sánchez, & Anguera, 2007; Fernandez, Camerino, Anguera, & Jonsson, 2009; Lapresa, Arana, Anguera, & Garzón, 2013; Sarmento et al., 2014; Tarragó et al., 2016), the lag sequential analysis (Bakeman & Quera, 2011) was conducted. This analysis is a process in which every action (conditioned behaviour) in a chain is dependent on the initial action (focal behaviour). It allows researchers to detect patterns and investigate related associations between actions based on the calculation of observed and expected frequencies, and to compare them using a corrected binomial test (Castellano et al., 2007; Tarragó et al., 2016). This method is applicable to datasets behaviours that occur in a certain order (Balmaseda, 2011; Tarragó et al., 2016), that is, in prospective and retrospective perspective (Castellano et al., 2007; González-Prado, Iglesias & Anguera, 2015; López-López, Menescardi, Estevan, Falcó, & Hernández-Mendo, 2015).

Recent studies conducted in combat sports by using lag sequential analyses found that in both fencing and taekwondo (González-Prado et al., 2015; Tarragó et al., 2016) high level athletes' tactical sequences are initiated by an attack and could be followed by counterattacks or defensive actions. However, in the case of taekwondo, it must be considered that only one lag was used to analyse the relationship between behaviours (González-Prado et al., 2015), that is, the analysis only considered the action that preceded and followed the focal behaviour. As in taekwondo there are different types of attacking and counterattacking actions (Menescardi, Lopez-Lopez, Falco, Hernandez-Mendo, & Estevan, 2015) and the combat does not stop after counterattacking, more lags could be considered for the study of tactical behaviour accurately. Thus, the aim of the current study was to examine Olympic taekwondo athletes' tactical behaviour by conducting sequential analyses of two lags.

## MATERIALS AND METHODS

### *Participants*

Seventy-five male matches of the London Olympic Games in 2012 were studied to analyse tactical actions. In the Olympics, only sixty-four male taekwondo athletes are allowed to compete: nineteen for each of the four weight categories (fly, feather, light and heavy). According to *The Belmont Report* (1978), since the videotapes analysed are in the public domain, it is not required to acquire informed consent from the athletes observed.

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### *Measures*

To analyse every bout, an *ad hoc* observational tool was created considering the following tactical actions: direct and indirect attacks, anticipatory, simultaneous and posterior counterattacks, defensive actions (cuts, blocks, dodges), and openings (Table 1).

Table 1. Categorical system of the observational tool.

| CRITERION | CATEGORY | CATEGORICAL CORE |
|---|---|---|
| Tactical action | Block (BLO) | Defensive actions to avoid the impact of a kick by placing one arm or leg between the protector and the leg of the opponent* |
| | Dodge (DO) | Defensive movement to avoid being kicked by the opponent* |
| | Cut (CUT) | Defensive forward movement to avoid being beaten by a close opponent, and to prevent the attacking action from being completed* |
| | Opening (OPE) | Movement to get control of the distance with the opponent or bridge the gap between both competitors. |
| | Direct attack (DA) | Offensive action without previous movement ending with an impact on the opponent's body** |
| | Indirect attack (IA) | Offensive action with previous movement such as a step, skip, opening, guard change, kicking trajectory modification, etc., ending with an impact on the opponent's body** |
| | Anticipated counterattack (AC) | Action that starts during the opponent's attack. The athlete kicks the attacker during the preparatory phase (guard) and/or initial phase (when the opponent's knee is being raised)** |
| | Simultaneous counterattack (SC) | Action that starts at the same time as the opponent's attack. 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 (PC) | Action that begins after the opponent's attack (during the descending phase, or when attacker's leg touches the ground). The athlete kicks at the same time as the opponent. This action (sometimes) includes a previous backward displacement to dodge the opponent's attack** |

Note. * means this action does not have a scoring objective. ** means this action is performed with the purpose of scoring.

### *Procedure*

Objective definitions of the observational tool were assessed by the codification of three bouts by three different observers (López-López et al., 2015). Inter- and intra-observer agreement were calculated by Cohen's kappa. In both cases, Cohen's kappa were above .90, showing a highly reliable tool and observers. According to previous studies (Casolino et al., 2012; Lupo, Condello, Capranica, & Tessitore, 2014), to avoid any inter-observer variation in the measures, an expert researcher in observational analysis in taekwondo (the first author of this study) codified all the bouts. Before coding all the bouts, a test-retest reliability analysis was conducted by coding a bout twice with 7 days of difference. Every coding was carried out using HOISAN 1.5.6 software (Hernández-Mendo, López-López, Castellano, Morales, & Pastrana, 2012).

### *Statistical Analysis*

Data were analysed using a binomial test with a level of significance of $p < .05$ to statistically compare observed (conditional probabilities which are computed according to the order of occurrence of the recorded behaviours) with expected frequencies (unconditional probabilities which reflect only the number of occurrences and correspond to the likelihood of chance) (González-Prado et al., 2015; Tarragó et al., 2016). Adjusted residuals were calculated to determine the strength of association between behaviours. Significant patterns were determined with positive adjusted residual (Z) > 1.96 to indicate excitatory relationships (López-López et al., 2015). The higher the Z value, the stronger the relationship between actions analysed (Castellano, 2000; Castellano, Hernández Mendo, & Haro, 2002). In the probabilistic models, different types of arrows were used to indicate the strength of the relationship (Castellano, 2000; Castellano, et al., 2002); that is, weak relationship was considered for $Z \leq 10$ (grey arrow), moderate for $10 < Z \leq 30$ (normal arrow), and strong for $Z > 30$ (bold arrow).

To study sequences of behaviours that occurred before and after the focal behaviour, lag sequential analyses were performed with 2 lags in both the prospective (positive lags) and retrospective (negative lags) perspectives. In this sense, retrospective associations between variables (i.e., focal and conditioned behaviours) could be considered as actions that precede the focal behaviour; while association between variables in prospective perspective could be considered as actions that followed the focal behaviour. Every lag sequential analysis was conducted with an attack or counterattack action (direct and indirect attack, anticipatory, simultaneous and posterior counterattack) used as focal behaviour while every tactical action was used as conditioned ones. The SDIS-GSEQ program (Bakeman & Quera, 1996) was used to conduct the sequential analysis.

## RESULTS

A total of 11752 actions were coded as follows: 537 blocks, 1911 dodges, 723 cuts, 1460 openings, 2281 direct attacks, 1711 indirect attacks, 269 anticipatory counterattacks, 1647 simultaneous counterattacks and 935 posterior counterattacks. The results of the sequential analysis are shown in Table 2.

Table 2. Adjusted residuals of focal and conditioned behaviours in two retrospective and prospective lags.

| Conditioned behaviours in retrospective perspective | | Focal behaviour | Conditioned behaviours in prospective perspective | |
|---|---|---|---|---|
| Lag -2 | Lag -1 | **Lag 0** | Lag 1 | Lag 2 |
| OPE (Z = 14.38) | DO (Z = 18.16) | **DA** | SC (Z = 20.04) | OPE (Z = 9.75) |
| DA (Z = 18.84) | SC (Z = 17.72) | | | DA (Z = 17.07) |
| IA (Z = 10.33) | | | | IA (Z = 8.34) |
| OPE (Z = 9.62) | DO (Z = 17.94) | **IA** | DO (Z = 4.99) | OPE (Z = 7.68) |
| DA (Z = 10.25) | SC (Z = 13.94) | | SC (Z = 18.91) | DA (Z = 6.22) |
| IA (Z = 14.55) | | | | IA (Z = 10.35) |
| DO (Z = 6.54) | DA (Z = 9.10) | **AC** | DA (Z = 9.40) | DO (Z = 3.91) |
| SC (Z = 6.16) | IA (Z = 14.49) | | IA (Z = 9.88) | SC (Z = 7.62) |

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| | | | | |
|---|---|---|---|---|
| SC (Z = 17.93) | DA (Z = 35.60) | **SC** | DA (Z = 25.32) | DO (Z = 14.06) |
| DO (Z = 24.04) | IA (Z = 29.38) | | IA (Z = 22.20) | SC (Z = 22.88) |
| DO ( Z = 11.48) | DA (Z = 35.60) | **PC** | DO (Z = 5.78) | DO (Z = 5.80) |
| SC (Z = 5.79) | IA (Z = 13.27) | | DA (Z = 15.32) | SC (Z = 6.67) |
| | | | IA (Z = 10.76) | |
| 322.12 | 5911.78 | $\chi^2$ | 4675.99 | 2344.05 |
| 32 | 32 | ***df*** | 32 | 32 |
| <.001 | <.001 | ***p*** | <.001 | <.001 |

*Note*: $\chi^2$ = chi square, *df* = degrees of freedom, *p* = significance, OPE = Opening, DA = direct attack, IA= indirect attack, SC = simultaneous counterattack, PC = posterior counterattack, AC = anticipatory counterattack.

Regarding direct attacks as focal behaviour, a significant pattern was found in lag -2 with openings, direct and indirect attacks; in lag -1 with dodges, and simultaneous counterattacks; in lag +1 with simultaneous counterattacks; in lag +2 with openings, direct and indirect attacks (Figure 1).

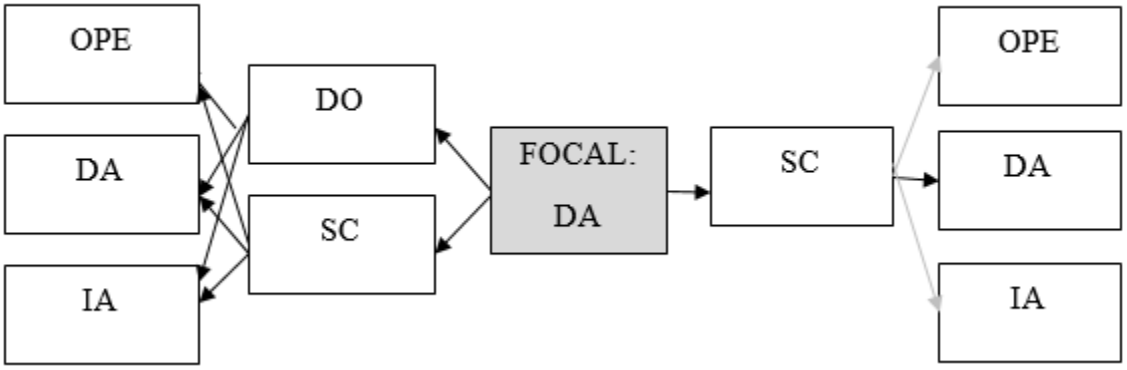


Figure 1. Probabilistic model of actions that precede and follow direct attacks. Note: grey arrow means Z < 10; black arrow means Z > 10.

Similarly, with regard to indirect attacks as focal behaviour, a significant pattern was found in lag -2 with openings, direct and indirect attacks; in lag -1 with dodges and simultaneous counterattacks; in lag +1, with also simultaneous and dodges; in lag +2 with openings, direct and indirect attacks (Figure 2).

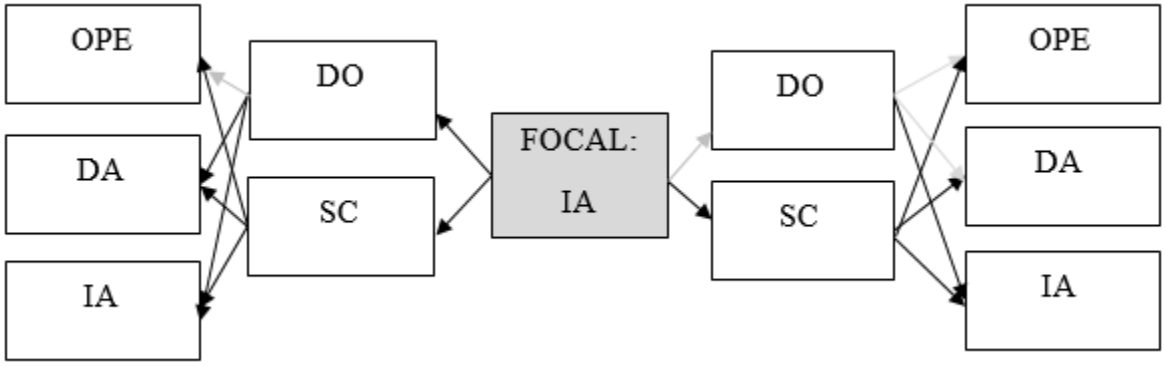


Figure 2. Probabilistic model of actions that precede and follow indirect attacks. Note: grey arrow means Z < 10; black arrow means Z > 10.

With regard to anticipatory counterattacks as focal behaviour, in lag -2 a significant pattern was found with counterattacks and dodges; in lag -1, with direct and indirect attacks; in lag +1, also with direct and indirect attacks; in lag +2 with dodges and simultaneous counterattacks (Figure 3).

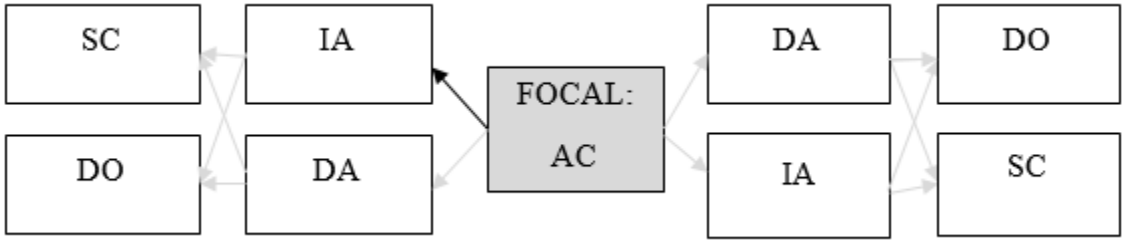


Figure 3. Probabilistic model of actions that precede and follow anticipatory counterattacks. Note: grey arrow means Z < 10; black arrow means Z > 10.

With regard to simultaneous counterattacks as focal behaviour, in lag -2 a significant pattern was found with simultaneous counterattacks and dodges; in lags -1 and +1, with direct and indirect attacks, in lag +2 with dodges and simultaneous counterattacks (Figure 4).

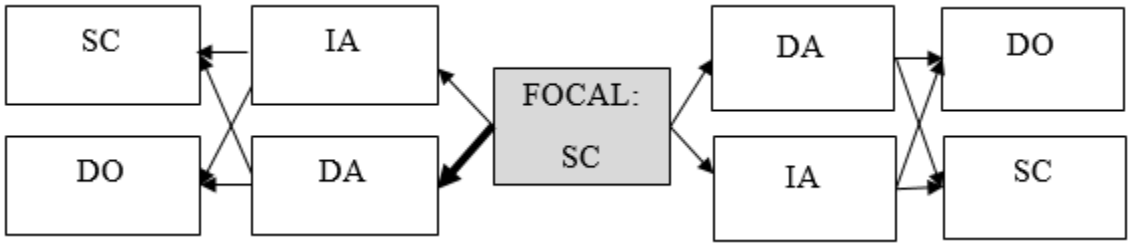


Figure 4. Probabilistic model of actions that precede and follow simultaneous counterattacks. Note: grey arrow means Z < 10; black arrow means Z > 10; bold arrow means Z > 30.

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Finally, with regard to posterior counterattacks as focal behaviour, in lag -2 a significant pattern was found with dodges and simultaneous counterattacks; in lag -1, with direct and indirect attacks; in lag +1 it was with dodges, direct and indirect attacks; in lag +2 with dodges and simultaneous counterattacks (Figure 5).

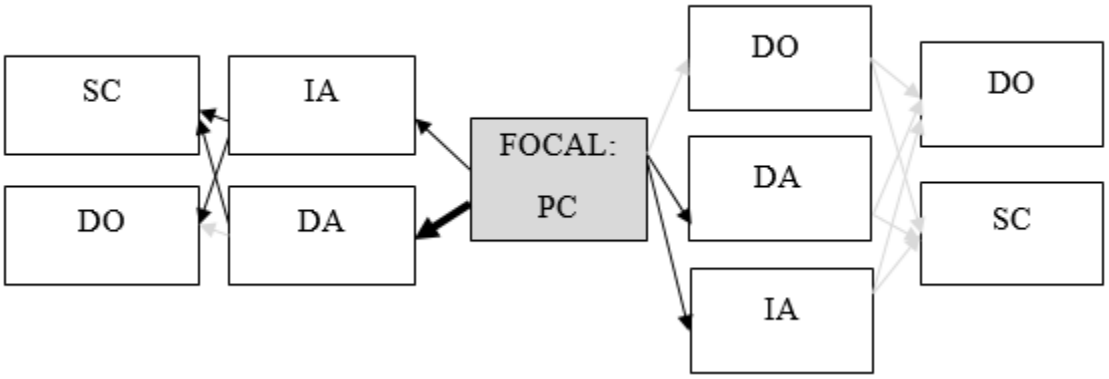


Figure 5. Probabilistic model of actions that precede and follow posterior counterattacks. Note: grey arrow means Z < 10; black arrow means Z > 10; bold arrow means Z > 30.

## DISCUSSION

This is the first study that performs a sequential analysis in Olympics in taekwondo. The results showed interchangeable patterns of attacks (direct or indirect) and openings actions followed by defensive (e.g., blocks, cuts or dodges) or counterattacking actions (e.g., anticipatory, simultaneous or posterior). These results confirmed theoretical tactical sequence proposals that supports the internal logic of taekwondo wherein an attack is followed by a counterattack, and so on (Joseph, 2012; Ruiz-Sanchis et al., 2016).

When attacks were considered as focal behaviours (direct and indirect attacks), in both cases, the results showed a previous sequence characterized by 'opening → dodges → attack (direct or indirect)'. This specific pattern seems to highlight the importance of athletes' active observation (i.e., opening action) as a determinant of the tactic in bouts (Iglesias, Gasset, González, & Anguera, 2010; Menescardi et al., 2015; Tornello, Capranica, Chiodo, Minganti, & Tessitore, 2013). The opening also relates with the existence of simultaneous counterattacks prior attacking, represented by the sequence 'opening → simultaneous counterattack → attack (direct or indirect)'. This means athletes perform an opening to check the opponent's reaction (Kil, 2006), who counterattack simultaneously and then the first athlete kick attacking (direct or indirect attack).

Additional patterns were also found prior the attacks characterized by the existence of simultaneous counterattack, that is, 'attack (direct or indirect) → simultaneous counterattack → attack (direct or indirect)'. It must be noted that simultaneous counterattack is the most frequent counterattack in World Championships (González, 2011) what is supported by the results in the current study. Despite the most frequent counterattack in college taekwondo athletes was the posterior (Falco et al., 2014), due to the athletes seem be able to kick powerfully (Machado, Osório, Silva, & Magini, 2010), it seems that Olympic taekwondo athletes preferred performing simultaneous for counterattacking. In comparison with anticipation and

posterior counterattacks (Falco, Molina-García, Álvarez, & Estevan, 2013), the simultaneous seems to allow Olympic athletes to get the little but enough time to choose the appropriate instant and type of kick for counterattacking. For elite taekwondo athletes as Olympics, it seems congruent they are proficient enough to move, choose and kick simultaneously reacting to the opponent's attack appropriately.

Continuing with attacks as focal behaviours, in prospective perspective, a pattern in both attacks existed, that is, 'attack (direct or indirect) → simultaneous counterattack → attack (direct or indirect) or opening'. This has also been found in retrospective perspective. Simultaneous counterattack is characterized by kicking in the same time meanwhile the athlete is moving to react as soon as possible to the counterpart's attack easily. The fact of finding this sequence in both retrospective and prospective perspectives could reflect a clench situation (i.e., a situation where both competitors are kicking due to the close distance in between) wherein both athletes kick the counterpart for scoring continuously.

Another new sequence of movements could be seen when dodges appears, that is, 'dodge → attack (direct or indirect) → simultaneous counterattack'. Dodges are the most common defensive actions used by taekwondo athletes (González, 2011), then it is congruent with this action had been related to both types of attacks. This sequence is congruent with the internal logic of the sport in which the competition distance adopted by athletes leads them to adapt their tactics to the opponent's one effectively (Torres, 1997). Then, when an athlete adopts a more conservative (defensive) role and increases the distance with the opponent, the opponent with a more proactive (offensive) role would tend to perform an indirect attack to reduce distance and kick the opponent.

When sequential analyses were conducted with counterattacks as focal behaviour, similar sequences were found in the retrospective perspective (prior the focal behaviour) for every of the three types of counterattacks. That is, 'simultaneous counterattack → attack (direct or indirect) → counterattack (anticipatory, simultaneous or posterior)' in addition to 'dodges → attack (direct or indirect) → counterattack (anticipatory, simultaneous or posterior)', with different strength in the relationships according to the type of counterattack as it was expected by Falco et al. (2014). On the one hand, in figure 3, only a moderate strength of relationship was found between indirect attacks and anticipatory counterattacks. Anticipatory counterattack is a good resource to apply in competition when athlete is able to recognize the attack of the opponent and react quicker than him/her. In this line, some authors suggested the use of anticipations on competition due to its effectiveness (González, 2011). On the other hand, the rest of relationships were less strong than those found in simultaneous and posterior counterattacks due to the lowest adjusted residual ($Z < 10$) found in anticipations. That could be due to the scarce presence of anticipations ($n = 269$) in comparison with simultaneous ($n = 1647$) and posterior ($n = 935$) counterattacks.

With regard to simultaneous and posterior counterattacks as focal behaviours, it must pointed out that in the lag -1 the relationship with direct attack (that is, direct attack is the action that precedes both types of counterattacks) was strong. In spite of the theoretical tactics that can be considered as appropriate (Falco et al., 2014), with posterior as the most effective counterattack when a direct attack is performed or anticipation for an indirect attack; Olympic athletes tend to perform not only posterior but also simultaneous counterattacks when direct or indirect attacks are performed. The use of simultaneous counterattack could be seen as a strategy used by international taekwondo athletes so that the opponent cannot determine the tactic behaviour easily. The stronger relationship of direct attacks with both simultaneous and posterior counterattacks can be explained by the high presence of direct actions in competition (González, 2011) supported by the findings of the present study.

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Considering the prospective perspective, similar patterns were also found for the three types of counterattacks, that is, 'counterattack (anticipatory, simultaneous or posterior) → attack (direct or indirect) → simultaneous counterattack' or 'counterattack (anticipatory, simultaneous or posterior) → attack (direct or indirect) → dodge'. In this case, it must be noted that anticipatory counterattack had a weak relationship with both attacks and successive actions (i.e., simultaneous counterattacks or dodges), while simultaneous and posterior counterattack had a moderate relationship with both attacks. Once more, in these cases, the results can imply a possible interchange of those actions in a clench situation. In this line, the inclusion of electronic chest protectors (in London 2012) (Moenig, 2015) could propitiate closer kick interchanges to score. In spite of posterior counterattack was pointed out as the most adequate for counterattacking a direct attack (Falco et al., 2014), the current study informs that Olympic athletes, may be due to the high level of opponents' performance have to prioritize the use of simultaneous counterattacks.

The sequential analysis allows researchers to recognise athletes' behavioural patterns. According to its nature, it must be noted that no consideration to time gaps between actions (focal and conditioned) is included in the analysis. In this regard, it is possible that an athlete kicked for attacking and the opponent blocked or cut the kick getting in clench situation forcing the referee to stop the bout; then a new sequence will start when referee restarts, and the first next action could be considered as a part of the previous sequence. For this reason, the sequential analysis was only carried out with 2 lags. Even so, the conclusions derived from the results must be highlighted with caution. To solve this limitation regarding the time gaps, some studies suggest the implementation of this kind of studies with a T-pattern analysis, which allows researchers to recognize repeated temporal and sequential structures in real-time behaviour records (Borrie, Jonsson, & Magnusson, 2002). Future studies with more than 2 lags, should be considered to split the sequences by including the time criteria so that the athletes' behavioural pattern is representative of a real bout.

## CONCLUSION

Sequential analyses confirmed the interchangeable pattern of attacking and counterattacking actions. The results of the present study suggested that athletes tend to counterattack, both direct and indirect attacks, simultaneously. With this condition in mind, coaches can prepare training sessions where athletes enhance their effectiveness against simultaneous counterattacks. Then, these sequential analyses in taekwondo can provide an insight for athletes' training in terms of behavioural patterns.

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