ORIGINAL ARTICLE

The scoring patterns depending on match conditions of world-class taekwondo athletes: application of association rules

Authors' Contribution:
A Study Design
B Data Collection
C Statistical Analysis
D Manuscript Preparation
E Funds Collection

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Abstract

Background and Study Aim: In sports matches, athletes mostly perform repetitive motions in predetermined spaces. Repetitive motions become different according to the features of teams or athletes, which give direct effect to match results. The aim of this study is knowledge about preferred by world-class taekwondo athletes scoring patterns.

Material and Methods: In this study, association rule was applied to identify data scoring patterns depending on match conditions of world-class taekwondo athletes. We recorded variables of match contents (match condition, position on court, match round, and type of attack) for instances of trunk scoring by subjects from 293 matches from the women's division of the 2017 *Muju International Taekwondo Competition*. It was found that the scoring frequency was 865 in the 293 matches and we performed frequency analysis and association rules analysis of match content variables based on the recorded data. Excel and a rules Viz in R package were used to statistical analyse data.

Results: First, the scoring patterns of taekwondo athletes in a tied state had the highest association with scoring in round 1, centre court position and defensive attack. Second, the scoring patterns in a winning state had a higher association with scoring in round 3, corner court position, and offensive attack. Third, the scoring patterns in a tied state had a higher association with scoring in round 1, centre court position and defensive attack. Fourth, the scoring patterns in a losing state had a higher association with scoring in round 3, dominant court position and offensive attack.

Conclusions: Considering that a large quantity of information other than variables selected in this study may be produced, this study cannot help having some limits. Further information can be identified when calculating the results by classifying weight class or athlete features. In future studies, that further information can be provided when processing studies considering trunk and face scoring and point deductions being highly associated with performance as well as the above mentioned limits.

Keywords: defensive attack • frequency • match contents • offensive attack • performance

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Match – *noun* **1.** a contest between opponents, especially a sporting contest **2.** somebody or something capable of competing equally with another person or thing [15].

Performance – *noun* the level at which a player or athlete is carrying out their activity, either in relation to others or in relation to personal goals or standards [15].

Attack – *verb* to attempt to defeat, or score against, an opponent in a competitive game or sport [15] – in this study **defensive-** or **offensive attack**.

Counterattack – *verb* to make an attacking move from a defensive position [15] – in this study **defensive attack**.

Defensive – *adjective* **1.** concentrating more on preventing an opponent from gaining an advantage than on scoring **2.** *US* relating to those players who have responsibility for defence [15].

Frequency – *noun* **1.** the number of times something takes place in a given time **2.** the rate of vibration in oscillations [15].

INTRODUCTION

In sports matches, athletes mostly perform repetitive motions in predetermined spaces. Repetitive motions become different according to the features of teams or athletes, which give direct effect to match results. Accordingly, a number of sports scientists have given continuous efforts to identify patterns of these repetitive motions of teams and athletes and emphasized its importance [1].

For pattern studies on motions of athletes in sport matches, they are being formed in diverse sport events regardless of their types including soccer, basketball, badminton, and taekwondo [2-5]. These studies mostly have performed for the purpose of comparing patterns of performance in competition according to differences of athletic performance and identifying performance patterns according to scoring.

Especially, for the taekwondo matches, much research has been given to substantial efforts for the development of taekwondo and improvement of performance, and performing studies to identify scoring patterns through analysis of match contents [1, 6, 7]. However most preceding studies identified scoring patterns of the athletes with a single variable, so they had some limits in providing meaningful information to actual application in matches. The limits are undeniable, considering that taekwondo generates various match factors to explain match content on the features of the event and the match factors generated simultaneously compose the performance pattern. When considering these limits in taekwondo matches, it is considered desirable to provide not only various information that has not been reported in studies performed up to now but also information that is actually needed by athletes and coaches.

Thus as a method able to perform analysis by considering the relationship between factors as well as input of various factors, association rule learning is introduced. This association rule method was introduced by Agrawal et al. [8] which has been applied in various areas by researchers. The association rule method is one of data-mining methods, which is known as a useful method to perform type analysis and pattern analysis [9, 10] and termed as market basket analysis from the aspect that it identifies buying patterns of customers visiting markets.

When applying this association rule method to analysis of taekwondo matches, it is not only useful to identify match patterns or scoring patterns of athletes but also to be able to obtain better results in terms such that various match factors can be applied to the analysis. Especially, it is considered that strategies depending on the match conditions can be planned when identifying scoring patterns by considering the match condition factors which have appeared as important factors in taekwondo matches [11].

Therefore, the aim of this study is knowledge about preferred by world-class taekwondo athletes scoring patterns.

MATERIAL AND METHODS

Research material

The matches of the women's division at the *2017 Muju World Taekwondo Competition* were analysed. In the matches of the women's division, only events generating scoring from trunk attacks were recorded. It was found that the total frequency of events generated for trunk scoring in 293 matches of taekwondo women's division was 865, which was used as research data.

Variable

In this study, the variables of match contents were set by primarily referencing preceding studies on taekwondo and competition rules of the World Taekwondo Federation. Then, 3 persons in the taekwondo expert community were selected to finally set 4 variables (match condition, match round, court position, attack type) of match contents generated in taekwondo matches as important variables, and concrete, variables: the match conditions were categorized into winning, tied, or losing states and the match rounds were categorized as round 1, 2, and 3 [12]; in addition, the position on the court was divided into dominant, centre, and corner court position [13] and the type of attack was divided between offensive and defensive attack (counterattack).

Data collection procedure

In this study, we visited personally the site of the *2017 Muju World-Class Taekwondo Competition* to collect research data. We recorded 293 matches of the women's division on video, which were converted to the form of match records by using a match analysis program, Sports Code and Excel 2013. For the match records, 4 variables (match condition, match round, position on court, and attack type) when scoring occurs in the recorded video of taekwondo matches were recorded.

Researchers for this study, who had at least 10 years of experience in taekwondo competition, underwent three weeks of match recording practice to increase the relevance of recordings.

Data processing

Point deduction frequency was analysed using Excel 2013. The analysis of association rules was conducted using the *Apriori* algorithm. The R statistics package from the open source *Arules* was used to run the *Apriori* algorithm to obtain and calculate *support*, *confidence*, and *lift* indexes. *Arules* Vis was also used to visualize the results of the analysis.

Association rule method

The association rule method is a form of machine learning technique to find buying pattern of shopping centre or mart customers. It started to identify purchasing patterns of customers visiting stores. This study uses the main algorithm from association rules learning called *Apriori*. In order to check correlation, it ranks data and information in three groups: *support*, *confidence*, and *lift*. In order to identify useful patterns in the association rule method, only values with at least 1 of *lift* were selected among the patterns satisfying minimum *support* and *confidence* set by the researches [14].

The *support* refers to a probability of variable A and B occurring at the same time in total scoring frequency and the *confidence* refers to a proportion of variable B occurring together with generation of the variable A. The *lift* refers to the proportion of variable B in total scoring frequency against the confidence probability, and values above 1 show the degree of correlation based on how high this figure is. Equations according to these are as follows.

Data processing

In this study, frequency analysis was performed to identify scoring frequency according to match conditions, using Excel 2013. In order to identify scoring patterns of taekwondo athletes in the women's division, association rule analysis was applied with *Apriori* algorithm. The *Apriori* algorithm was analysed with a rules, an open source of R statistics package, through which indexes of *support*, *confidence* and *lift* were calculated to identify scoring patterns.

RESULTS

Analysis of point scoring frequency according to match contents of taekwondo athletes in women's division

As the results indicate, it was found that for the match round, the frequency of scoring from trunk attack in round 3 (339; 39.2%) was the highest. For the match condition, the losing state (509; 58.8%) showed the highest frequency, for the position on court, the dominant court position (459; 53.0%) showed the highest frequency and for the attack type, offensive attack (515; 59.5%) was calculated as the highest frequency (Table 1).

Scoring patterns of taekwondo athletes in women's division using the association rule analysis

In the analysis of association rule, *support*, confidence, and number of rule should be set in advance. In this study, association rule values were calculated by setting the minimum *support* value to 0.02 and *confidence* to 0.3 since too high value of *support* and *confidence* may generate problems where that association rule cannot be produced. In addition, 4 types of rules were set to include all variables recorded in case of scoring.

$$Support\ (A,B) = P(A \cap B) = \frac{Frequency\ of\ Variable\ A\ and\ Varaible\ B\ occuring\ simultaneously}{total\ point\ scoring\ frequency}$$

(Equation 1)

$$Confidence\ (A \rightarrow B) = \frac{P(A \cap B)}{P(A)} = \frac{Frequency\ of\ Variable\ A\ and\ Varaible\ B\ occuring\ simultaneously}{Frequency\ of\ variable\ A}$$

(Equation 2)

$$Lift = \frac{P(B|A)}{P(B)} = \frac{P(A \cap B)}{P(A)P(B)} = \frac{Confidence}{P(B)}$$

(Equation 3)

Table 1. Analysis of point scoring frequency according to match contents of taekwondo athletes.

Variable		Frequency	%
important	concrete		
Match round	Round 1	251	29.0
	Round 2	275	31.8
	Round 3	339	39.2
Match condition	Winning state	207	24.0
	Tied state	149	17.2
	Losing state	509	58.8
Position on court	Dominant court position	459	53.0
	Centre court position	263	30.5
	Corner court position	143	16.5
Attack type	Offensive attack	515	59.5
	Defensive attack	350	40.5

As the results, a total of 71 association rules were calculated, the range of *support* was 0.021~0.064, the range of *confidence* was 0.301~0.871, and the range of *lift* was 0.618~2.329 (Table 2).

The results of trunk scoring patterns of taekwondo athletes in women's division showed that the highest association value (*lift*: 2.328) was found in round 1, defensive attack, centre court position, and tied state. The second highest association value (*lift*: 2.087) was obtained in round 3, defensive attack, corner court position, and the third highest association value (*lift*: 2.005) was obtained in round 1, defensive attack, centre court position, and tied state (Table 2).

Scoring patterns of taekwondo athletes in women's division according to match conditions

Scoring patterns of taekwondo athletes in winning state

In the analysis of scoring patterns of taekwondo athletes in women's division according to match conditions, 0.01 of support and 0.03 of confidence were set. In addition, 4 types of rules were set to include all variables recorded in case of scoring. As the results indicate, the scoring pattern of taekwondo athletes in winning state showed the highest association value (*lift*: 1.564) in round 3, offensive attack, and corner court position. The second highest association value was obtained in round 3, defensive attack (*lift*: 1.487), and the third highest association value (*lift*: 1.215) was obtained in round 2, defensive attack, and centre court (Table 3).

Scoring patterns of taekwondo athletes in tied state

The results showed the highest association value (*lift*: 2.328) in round 1, defensive attack, and centre court. The second highest association value was obtained in round 1, offensive attack (*lift*: 2.019), and the third highest association value (*lift*: 1.939) was obtained in round 1, offensive attack, and centre court (Table 4).

Table 2. Analysis of scoring pattern of taekwondo athletes by applying the association rule: top 5 values (rank) in *lift*.

Rank	Variable		Index		
	LHS	RHS	support	confidence	lift
1	Round 1, centre court, defensive attack	Tied	0.0229	0.3921	2.328
2	Round 3, wining, defensive attack	Corner court	0.0378	0.3586	2.087
3	Tied, centre court, defensive attack	Round 1	0.0229	0.5882	2.005
4	Round 3, dominant court, offensive attack	Losing	0.0378	0.6000	1.984
5	Round 2, losing, offensive attack	Dominant	0.0263	0.4600	1.940

Table 3. Analysis of scoring patterns of taekwondo athletes in winning state: top 3 values (rank) in lift.

Rank	Variable LHS	Index		
		support	confidence	lift
1	Round 3, corner court, offensive attack	0.0217	0.8260	1.564
2	Round 3, corner court, defensive attack	0.0378	0.7857	1.487
3	Round 2, centre court, defensive attack	0.0492	0.6417	1.215

Table 4. Scoring patterns of taekwondo athletes in tied state: top 3 values (rank) in *lift*.

Rank	Variable LHS	Index		
		support	confidence	lift
1	Round 1, centre court, defensive attack	0.0229	0.3921	2.328
2	Round 1, dominant court, offensive attack	0.0194	0.3400	2.019
3	Round 1, centre court, offensive attack	0.0366	0.3265	1.939

Table 5. Analysis of scoring patterns of taekwondo athletes in losing state: top 3 values (rank) in *lift*.

Rank	Variable LHS	Index		
		support	confidence	lift
1	Round 3, dominant court, offensive attack	0.0378	0.6000	1.984
2	Round 3, centre court, offensive attack	0.0538	0.4122	1.363
3	Round 2, dominant court, offensive attack	0.0263	0.3770	1.246

Scoring patterns of taekwondo athletes in losing state

The results showed the highest association value (*lift*: 1.984) in round 3, offensive attack, and dominant court position. The second highest association value was obtained in round 3, offensive attack, centre court position (*lift*: 1.363), and the third highest association value (*lift*: 1.246) was obtained in round 2, offensive attack, and dominant court position (Table 5).

DISCUSSION

The match conditions of taekwondo competitions are divided into 3 types (winning, tied, and losing state) and are considered as important factors – game strategies and patterns of athletes vary according to the 3 types of match conditions. As a number of researchers studying taekwondo have reported that match conditions should be considered in analysis of matches, their importance is being emphasized more and more [1, 14]. Thus in this study, scoring patterns of taekwondo athletes in the women's division according to match conditions were identified, applying association rule method.

First, a feature of current competition matches can be found from scoring frequency of Taekwondo athletes in the women's division. In the study of position on court and type of attack in variables of match contents, it was shown that the scoring frequencies for dominant court position and offensive attack were higher. Higher scoring frequencies for dominant court position and offensive attack can be interpreted as to perform offensive taekwondo during the matches. These points can be explained as a result of revisions of game rules and court specifications by the World Taekwondo Federation to promote offensive taekwondo, as a part of an effort to increase excitement and interest in taekwondo [14]. Namely, it can be confirmed indirectly that the taekwondo matches are advancing in the direction intended by the World Taekwondo Federation.

Besides, as results of analysing scoring patterns of taekwondo athletes in women's division indicate, scoring in round 1, tied state, and centre court position showed the highest association value. With scoring patterns occurring at the initiation point of taekwondo matches, information that attention is needed in attempting offensive attacks at the centre court position in early time of matches can be identified. In addition, the results analysing scoring patterns according to match conditions showed the highest value in round 3, corner court position, and offensive attack is in the winning state. Although these results was obtained because many athletes perpetuate a match relatively more on the corner court position in a winning state as features of taekwondo, interestingly frequency of scoring was also higher by offensive attack even in the corner court position. It is considered that as stepping out of the boundary line was changed from a warning to point deduction, attempts to offensively attack, and therefore scoring, increased further accordingly. In the losing state, the highest association value was obtained in round 3, dominant court position, and offensive attack. When studying common points in losing and winning state, it was found that offensive attacks had higher association value with scoring. In other words, it can be explained that offensive attacks rather than defensive attacks had a higher success rate of scoring.

Detailed conclusions obtained from this study are as follows. First, the scoring patterns of taekwondo athletes had the highest association with scoring in round 1, centre court position and defensive attack in tied state. Second, the scoring patterns in losing state had higher association with scoring in round 3, corner court position, and offensive attack. Thirdly, the scoring patterns in tied state had higher association with scoring in round 1, centre court position, and defensive attack. Fourth, the scoring patterns in losing state had higher association with scoring in round 3, dominant court position and offensive attack.

It is suggested that these study results complemented the limits of preceding studies through contents which had not be considered in previous studies on scoring patterns in taekwondo [6, 7] and new methodologies. Especially, it is considered that the scoring pattern analysis can be used as basic information in strategy planning and training as well as delivered to athletes and coaches as meaningful information.

CONCLUSIONS

This study has considerable significance as it analysed taekwondo matches by applying various variables and new statistical methods. However, considering that a large quantity of information other than variables selected in this study may be produced, this study cannot help having some limits. Especially it seems that further information can be identified when calculating the results by classifying weight class or athlete features. In future studies, it is considered that further information can be provided when processing studies considering trunk and face scoring and point deductions being highly associated with performance as well as the above mentioned limits.

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