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Predicting taekwondo winners in high-level competition using ranking scores and country performance scores: an analysis of the 2019 World Taekwondo Championship

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Key words: rank score, country performance, *taekwondo*

Abstract

Background**.** The ranking system can be considered a measure of athletes' performance. In addition, countries with high performance are expected to have better athletes.

Problem and Aim. The present study aimed to verify whether ranking scores and country performance by competitors differ between winners and losers; and whether ranking scores and country performance by competitors could predict winners and losers in a high-level taekwondo competition.

Methods. A total of 759 combats at the 2019 World Taekwondo (WT) Championship were analyzed in the present study. We used as variables the ranking scores and country performance score (CPS) calculated based on the number of Olympic medals won by a given country. The Bayesian t-test was used to estimate the difference in the rank score and CPS between winners and losers, and Support Vector Machine was used to predict the winners.

Results. In summary, the results showed that both the ranking scores and CPS of losing athletes were lower than winners. Moreover the ranking score and CPS of the athlete and their opponent predicted the winners with a moderate degree of accuracy (higher than 0.70) in both the grouped sample and females separated out, but had low accuracy (0.69) in male athletes.

Conclusions. Considering the complexity of a Taekwondo competition, it is possible to interpret that the ranking scores and the CPS of the competitors are important variables in predicting winners in high-level taekwondo competition.

1. Introduction

Taekwondo was introduced as a demonstration sport in the 1988 and 1992 Olympic Games before becoming an official sport in the 2000 Olympics [Kazemi *et al.* 2006]. Since its beginning as an Olympic sport, Taekwondo has increased its popularity and gained interest from researchers [Perez-Gutierrez *et al.* 2017]. In addition, it has undergone several changes [e.g., Protector Scoring System (PSS); and systematization of the ranking system] aiming to improve the technical quality as well as to make the sport more attractive to the spectators.

One of the changes that occurred in Taekwondo was the adoption of a scoring system of the competitions, called the ranking system [WT 2019b; WT 2019c].

The ranking system is controlled by the World Taekwondo (WT), the International Federation governing the sport of Taekwondo, and is applied to all of its promoted competitions. The WT ranking system is published monthly in two documents: WT World Ranking and WT Olympic Ranking, because the competitions differ in terms of weight divisions [WT 2019b]. The World Championship has eight senior weight divisions for men and women, whereas the Olympic Games has only four [WT 2019c].

This ranking system allocates participation places for the best-ranked athletes in the most important competitions, i.e., the Olympic Games. In other words, the ranking position defines the main competitions (those with the highest scores for the rank), ensures the participation of the athletes in the competitions promoted by WT (as it is necessary to participate in competitions to score in the ranking system), as well as contributes to the best athletes qualifying to the Olympic Games. In addition, in high-level Taekwondo competitions the athletes are seeded based on WT World Ranking to avoid the best athletes competing against each other in the initial phases of competitions, as done in other combat sports [Breviglieri *et al.* 2018; WT 2019a]. Therefore, the ranking system can be considered a measure of athletes' performance and has been previously investigated in judo athletes [e.g., Breviglieri *et al.* 2018; Courel-Ibanez *et al.* 2018; Franchini, Julio 2015], but, to the best of our knowledge, it has not been investigated in taekwondo. Thus, even though not being investigated in taekwondo yet, it is possible to suggest that winners have higher ranking scores than losers, and consequently better ranked athletes are more likely to win a combat when competing with worse ranked athletes.

Moreover, Albuquerque *et al*. [2015] argued that the number of athletes available to participate in a sport, which is dependent on the sports' popularity in a given country, may increase the level of competitiveness within that country. Furthermore, countries with high competitiveness are expected to have better athletes, and ultimately, better results in important competitions, or in other words, a higher performance in the sport. In short, it is hypothesized that athletes from higher performance countries in Taekwondo are more likely to win a combat than athletes from lower performance countries.

Therefore, the primary aim of the current study was to verify whether ranking score and country performance from competitors differ between winners and losers in a high-level Taekwondo competition. In this line, we hypothesize that winners will have higher ranking and country performance scores than losers. Also, the secondary aim of this study was to investigate whether ranking scores and country performance by competitors could predict winners and losers in a high-level competition. Further, we hypothesize that rank and country performance scores will predict the winners in high-level competitions.

2. Methods

2.1. Data, Data Preprocessing, and Analysis

Figure 1 shows the flowchart of all procedures. Initially, information about the combats and the April 2019 World Kyorugi Ranking scores of all athletes who participated in the 2019 World Championship held in Manchester in May 2019 were extracted from the official WT website. Combat information (competitors, competitor's nationality, athlete scores, and competition phase) was manually tabulated. After the combat data was tabulated in the Microsoft Excel, a Visual Basic for Applications (VBA) routine was developed to add to the combats the measures extracted by ranking data (April 2019) and the country performance scores (CPS). In the end, the dataset consisted of the following variables: Athlete 1 Name, Athlete 1 Country, Athlete 1 Score, Athlete 2 Name, Athlete 2 Country, Athlete 2 Score, Competition Phase (qualifying, eighth-finals, quarterfinals, semifinals, and finals), Athlete 1 ranking score, Athlete 1 CPS, Athlete 2 ranking score, Athlete 2 CPS, gender and weight division.

CPS was calculated based on the number of Olympic medals won by a given country[1], because it is the most important Taekwondo competition. For the calculation, we used the WT ranking system as a reference [WT 2019b], in which the gold medal receives 100% of the points, the silver medal receives 60% of the points awarded to the gold medal, and in the end, the bronze medal receives 60% of the points awarded to the silver medal [WT 2019b]. Thus, the number of gold medals in the Olympic Games was multiplied by 200, silver by 120, and bronze by 72. For example, South Korea has 12 gold, 2 silver, and 5 bronze Olympic medals. Therefore, the result of the CPS of South Korea is: (12 * 200) + (2 * 120) + (5 * 72) = 3000 points.

A total of 766 combats (qualifying = 525, eighth-finals = 129, quarterfinals = 64, semifinals = 32, and finals = 16) were collected. Seven combats were excluded because one of the athletes was disqualified (DSQ). Therefore, 759 (qualifying = 518, eighth-finals = 129, quarterfinals = 64, semifinals = 32, and finals = 16) combats (male combats = 429, female combats = 330) were used in the present study.

One possibility to test our hypothesis to predict athletes' wins would be to use Machine Learning (ML) to verify the accuracy of the models by using the ranking score and the country tradition of the competitors in one important competition, both separated and combined. ML "learns" a model from a training dataset to predict the target variable on a test dataset [Cruz, Wishart 2007]. One of the common ML involves predicting a target variable in previously unseen data, i.e., its test dataset. Many

[1] https://www.sports-reference.com/olympics/sports/TKW/

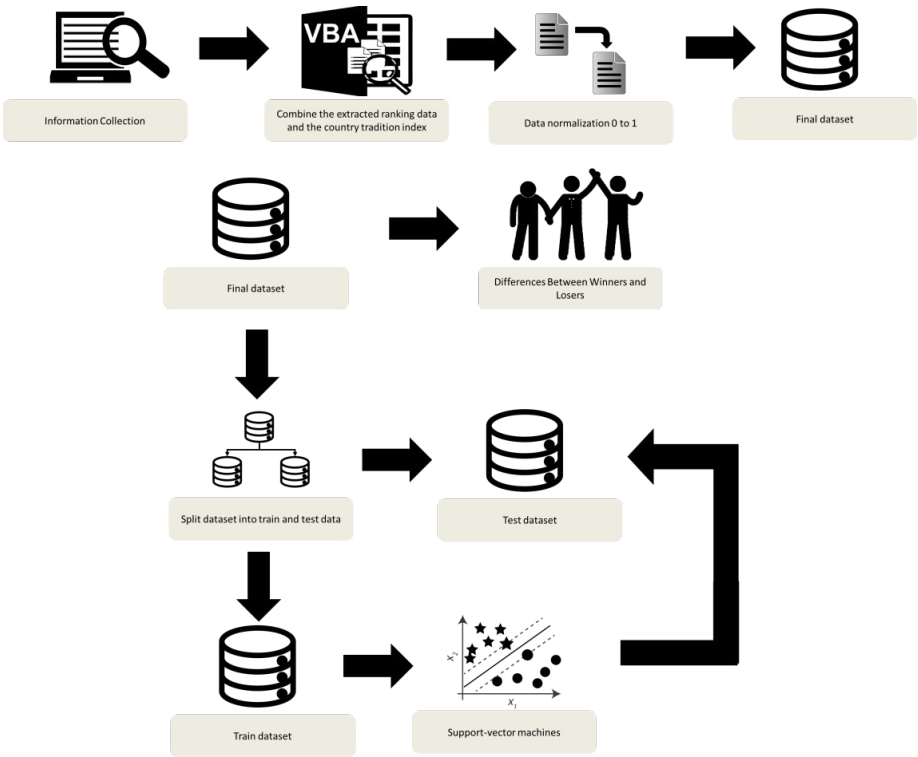

Figure 1. Flowchart of the design procedures

different techniques can be implemented as the learning methods [Bunker, Thabtah 2019], in which the Support Vector Machine (SVM) is a well-documented technique [Koseler, Stephan 2017]. In summary, for a given set of training data, each marked as belonging to one of two categories (Athlete 1 or Athlete 2), the SVM training algorithm develops a model for classifying the given data. However, it is frequently not possible to clearly separate the given dataset. As one of the solutions for this problem, four kernel functions [1) Linear, 2) Polynomial, 3) Radial, and 4) Sigmoid] can be adopted.

To generate train and test datasets, we used the sample.split function of caTools package of R in which we used the SplitRatio of the .75. Thus, the training dataset consisted of 75% of the data that were randomly selected. On the other hand, the test dataset consisted of 25% of the data randomly generated.

Firstly, the BEST package of R, a "Bayesian t-test" alternative, was used, providing estimates for the differences of the rank and CPS between winners and losers. The Bayesian approach shows probability statements rather than p-values [Kruschke 2013]. Thus, we used the Bayesian analysis to test how large were the differences in the rank and country tradition index between winners and losers.

Moreover, we used the e1071 package of R, using the SVM function to calculate the SVM models in the training dataset and predict function was used to predict the winners and losers in the test dataset. At the end, confusion Matrix function of the caret package of R was used to calculate the accuracy of the model to predict the winner of the combat. As suggested by Swets [1988] we used the following values for the accuracy interpretation: 0.50 to 0.69, rather low accuracy; 0.70 to 0.89, moderate accuracy; and higher than 0.90, rather high accuracy.

3. Results

For the comparison between winners and losers, we conducted a Bayesian estimation, in which our results show that the rank score of the losing athletes were lower than the score of the winning athletes in the whole sample [differences of means = 0.145; highest density interval (HDI) = 0.122 to 0.168], in males (differences of means = 0.174; HDI = 0.144 to 0.204) and females (differences of means = 0.103; HDI = 0.067 to 0.138). The 95% HDI of the differences of means falls above zero, and 100% of the credible values are greater than zero in winners versus losers in all analyses (Figure 2).

With regards to CPS, the results show that the losing athletes scored lower than winning athletes in the whole sample (differences of means = 0.076; HDI = 0.066 to 0.086), in males (differences of means = 0.064; HDI = 0.054 to 0.745) and females (differences of means = 0.091; HDI = 0.070 to 0.111). The 95% HDI of the differences of means falls above zero, and 100% of the credible values are greater than zero in winners versus losers in the CPS in all analyses (Figure 3).

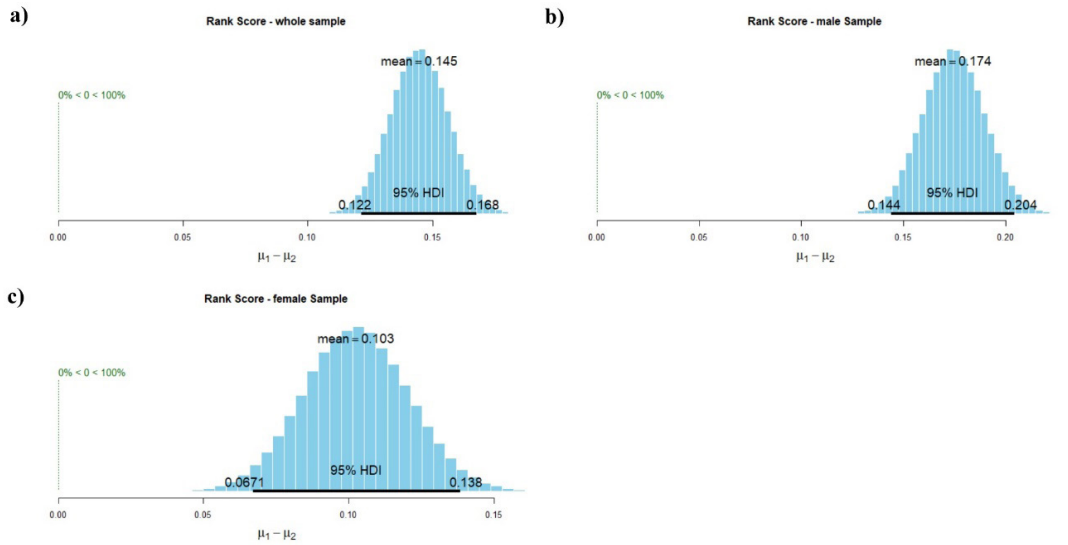

Figure 2. Bayesian estimation to compare the rank scores between winners and losers in the a) whole sample, b) male, and c) female groups.

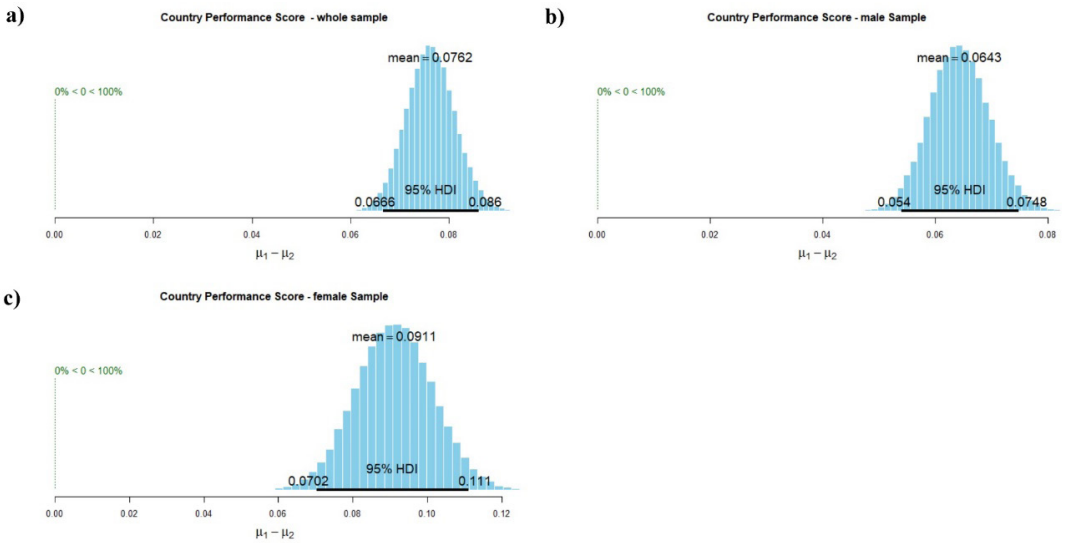

Figure 3. Bayesian estimation to compare the country performance score between winners and losers in a) whole sample, b) male, and c) female groups

To verify whether the rank score and CPS of the competitors could predict winners, we used four kernel functions (Linear, Polynomial, Radial Basis Function, and Sigmoid) in the whole sample, in male and female athletes. Thus, three models were tested: 1) the rank score of the athlete and the rank score of the opponents (Model 1); 2) the CPS of the athlete and the CPS of the opponents (Model 2); and 3) the rank and CPS of the athlete and the rank and CPS of the opponents (Model 3).

The analysis of the athlete and opponent ranking score (Model 1) presented low to moderate accuracy in the better-performed model of 0.66 [95% confidence interval (CI) 0.59-0.72] for all participants, 0.70 (95%CI 0.61-0.78) for males, and 0.69 (95%CI 0.58-0.78) for females (Figure 04).

For the CPS of the athlete and opponent (Model 2), the results also showed low to moderate accuracy: 0.64 (95%CI 0.57-0.70) for all participants, 0.71 (95%CI 0.62-0.79) for males, and 0.73 (95%CI 0.63-0.82) for females (Figure 05).

At the end, the rank score and CPS of the athlete and the rank score and CPS of the opponent (Model 3) showed accuracy of 0.70 (95%CI 0.63-0.76) for all participants, 0.69 (95%CI 0.59-0.77) for males, and 0.74 (95%CI 0.64-0.83) for females (Figure 06).

4. Discussion

The present study aimed to verify whether ranking score and country performance score by competitors could predict Taekwondo winners and losers in a high-level competition, as well as to test the accuracy of the algo-

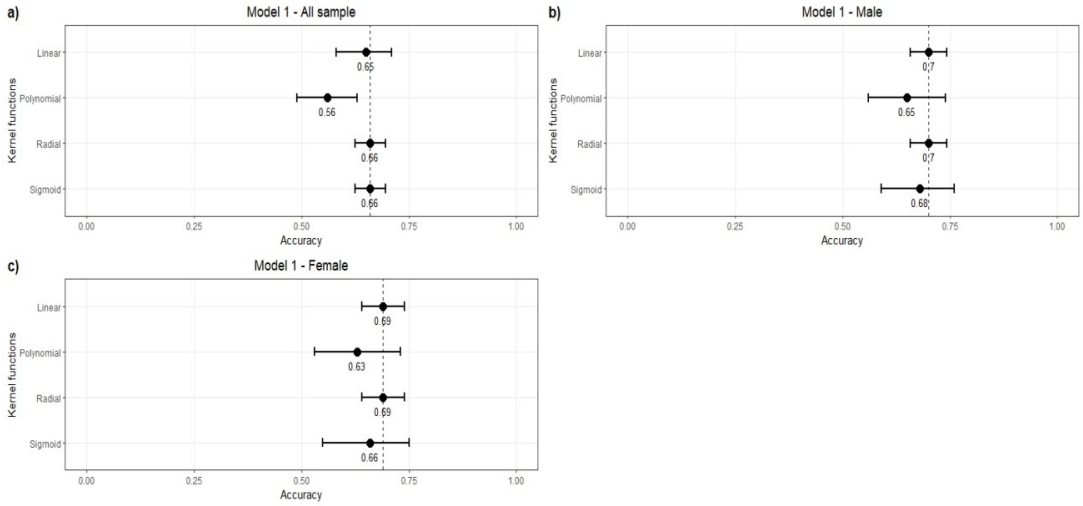

Figure 4. Accuracy plot of model 1 with all kernel functions. a) whole sample, b) males, c) females

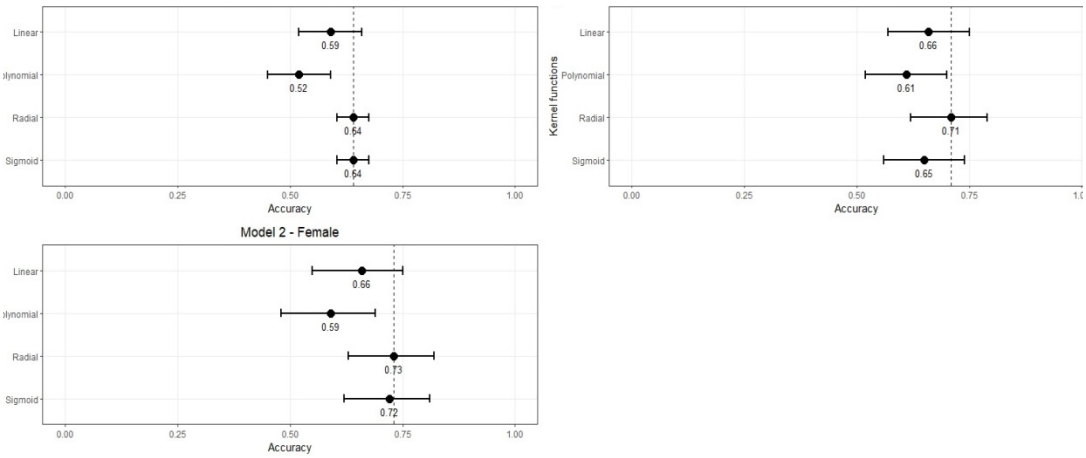

Figure 5. Accuracy plot of model 2 with all kernel functions. a) whole sample, b) males, c) females

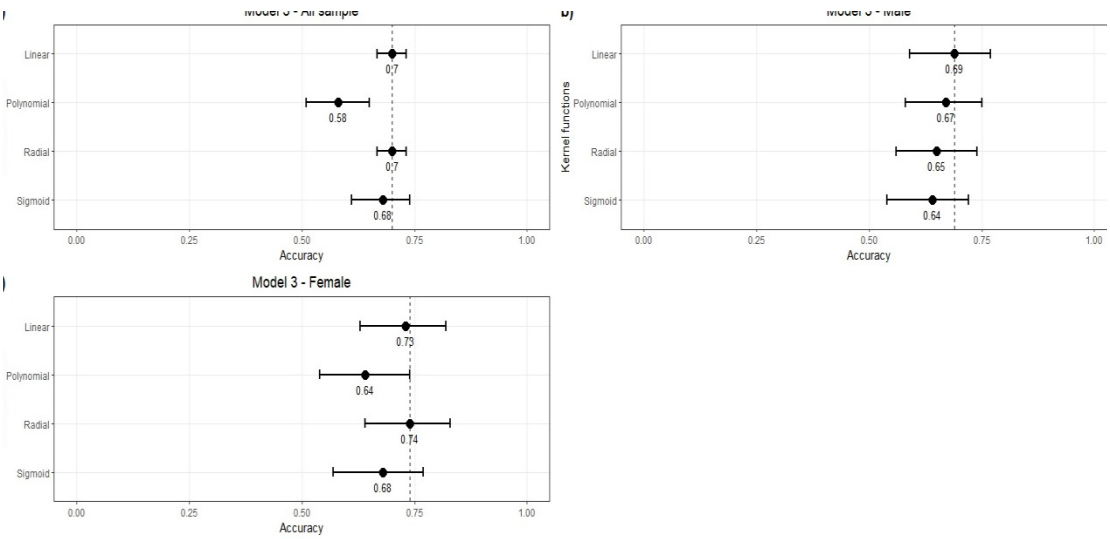

Figure 6. Accuracy plot of model 3 with all kernel functions. a) whole sample, b) males, c) females

rithm separated by the athletes' sex. In summary, the rank score and CPS of the losers were lower than those of winners in the whole sample and separated by sex. Besides, our results showed that Model 3, which used the ranking and CPS of the athlete and its opponent was the best predictor of the winners, presenting a moderate degree of accuracy (higher than 0.70) in the whole sample and females, and 0.69 in male athletes.

Firstly, as expected, the ranking score of athletes seems to be a variable of athlete quality [Malcata *et al.* 2014]. That is, athletes with the highest rank scores were the athletes who have achieved the best results in competitions [Breviglieri *et al.* 2018; Courel-Ibanez *et al.* 2018; Franchini, Julio 2015]. However, it is important to note that some points should be considered and analyzed in future studies, such as whether the rank score is related to the best results achieved in the best competitions (quality), or if the ranking score was achieved by the presence of the athlete in several competitions (quantity). In short, our results indicated that better ranked athletes seem to have higher chances of winning than worse ranked athletes. Thus, as proposed by the World Taekwondo, the rank score can be used as a performance measure of the athletes, and can be used to allocate the best ranked athletes in specific pools in the most important competition, i.e., the Olympic Games, as well as to avoid the best athletes competing against each other in the initial phases of competitions [Breviglieri *et al.* 2018; WT 2019a]. However, it is important to highlight that Model 1, which represents the rank of the athlete and his/her opponent, presented low to moderate accuracy (0.66-0.70), indicating that the ranking score is not able to exclusively explain wins and losses in the high-level Taekwondo competition.

Secondly, to the best of our knowledge, this is the first study that investigated if the athlete's country performance can predict winners in Taekwondo competitions. As can be seen from the results of Model 2, the prediction showed a moderate degree of accuracy (ranging from 0.64 to 0.73). In addition, the fact that the country performance of the athlete appears to be a variable similar to rank scores to predict the winner in the high-level competition is highlighted. Malcata *et al.* [2014] argued that a simple count of the medals shows several problems to assess a country's performance. Firstly, the method excludes performances of non-medal athletes and consequently does not reflect a country's talent base. Secondly, the count of medals is biased against countries with more talent because the major Taekwondo competitions limit the number of participants per country, and at the end, the medal counts are low and, therefore inherently imprecise [Malcata *et al.* 2014]. Thus, although we agree with the arguments about the limitation of our CPS, we showed that it is practically similar to the rank score to predict the winner in high-level Taekwondo competitions. Moreover, differently from the rank score that reflects the quality of the athlete, our analysis on the CPS appears to reflect country performance and the internal competition in that country.

As well-documented previously, the country medals in Olympic Games reflect the investment in sports systems and structure [Nevill *et al.* 2009; Nevill *et al.* 2012; Rees *et al.* 2016]. It is possible to assume that the interaction of complex factors can contribute to the number of medals in the high-level competitions (e.g., World Championships or Olympic Games), such as funding support, infrastructure and facility, coach development programs, local of the competition, period between successive competitions, and many others [Julio *et al.* 2013; Franchini *et al.* 2017; Nevill *et al.* 2009; Nevill *et al.* 2012; Rees *et al.* 2016]. In addition, Albuquerque *et al.* [2015] argued that the number of athletes available to participate in a sport, which is dependent on the popularity (cultural aspects) of the sport in a given country, may increase the level of competitiveness within that country (improve the quality of the athletes). As a result, it is expected that more competitive countries would deliver better results (higher country performance score) than less competitive countries. Moreover, it is important to highlight the importance of international junior success for success in senior Taekwondo competitions [Li *et al.* 2018]. For instance, Li *et al.* [2018] suggest that 47.4% of the junior medalists and 96.6% of the early achievers (who won a senior international medal whilst at a junior age) went on to win international Taekwondo medals at a senior age. In summary, although the count of the medals may have some limitations, our results showed that our CPS could predict with moderate accuracy the winners in a high-level Taekwondo competition.

At the end, the models analyzed (1, 2, and 3) in the present study presented a moderate degree of accuracy (ranging from 0.64 to 0.74) to predict winners in high-level competitions. However, it is important to highlight the fact that only two variables (rank and country performance) of the competitors were used in the algorithm. Thus, considering the complexity of a Taekwondo competition in which several factors can influence the result [Franchini, Julio 2015; Franchini *et al.* 2017; Nevill *et al.* 2009; Nevill *et al.* 2012; Rees *et al.* 2016], it is possible to interpret that the rank score and country performance of the competitors are important variables to predict winners and losers in a high-level competition.

Therefore, countries must establish strategies to improve their position in the ranking, such as participating in an optimal number of competitions and organizing championships to gain the advantage of competing at home [Julio *et al.* 2013]. In addition, countries' sports government agencies should adopt strategies to improve internal competitiveness and support athletes' participation in high-level competitions that contribute to the ranking system, in order to foster the development of the sport in the country.

Conclusions

Our results showed that both the ranking score and the country performance score of the losing athletes were lower than those of the winners in the whole sample and separated out by gender. In addition, our results showed that Model 3, which used the ranking and country per-

formance scores of the athlete and its opponent, was a predictor of the winners in high-level Taekwondo competition with moderate accuracy.

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Typowanie zwycięzców na zawodach Taekwondo wysokiego szczebla według wyników rankingowych i wyników krajowych: analiza Mistrzostw Świata w Taekwondo w 2019 r.

Słowa kluczowe: wyniki rankingowe, wyniki krajowe, taekwondo

Streszczenie

Tło. System rankingowy można uznać za miarę osiągnięć sportowców. Ponadto oczekuje się, że kraje o wysokich wynikach będą miały lepszych sportowców.

Problem i cel. Celem niniejszego badania było sprawdzenie, czy wyniki rankingowe i wyniki poszczególnych krajów różnią się w przypadku zwycięzców i przegranych; oraz czy na podstawie wyników rankingowych i wyników poszczególnych krajów można przewidzieć zwycięzców i przegranych na zawodach Taekwondo wysokiego szczebla. Metody. W niniejszej pracy przeanalizowano łącznie 759 walk Mistrzostw Świata w Taekwondo (WT) 2019. Jako zmienne wykorzystano wyniki rankingowe i wyniki krajowe (CPS) obliczone na podstawie liczby zdobytych przez dany kraj medali olimpijskich. Do osza-

cowania różnic w wynikach rankingowych został użyty T-test Bayesa, test określający wynik krajowy (CPS) pomiędzy zwycięzcami i przegranymi, a do przewidywania zwycięzców została użyta maszyna wektorów nośnych (Support Vector Machine). Wyniki. Podsumowując, wyniki pokazały, że zarówno wynik rankingowy jak i CPS zawodników przegrywających były niższe od zwycięzców. Ponadto, wynik rankingowy i CPS zawodników oraz ich przeciwników przewidywały zwycięzców z umiarkowaną dokładnością (wyższą niż 0,70) w grupie testowej oraz w grupie kobiet, ale z niską dokładnością (0,69) w grupie mężczyzn.
Wnioski. Biorąc pod uwagę złożoność zawodów Taekwondo, możliwa jest interpretacja, z której wynika, że wynik rankingu i CPS zawodników są ważnymi zmiennymi służącymi do przewidzenia zwycięzców na zawodach Taekwondo wysokiego szczebla.