

ORIGINAL ARTICLE



Application of PageRank Model for Olympic Women's Taekwondo Rankings: Comparison of PageRank and Accumulated Point Index System

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ABSTRACT

Background. Although the World Taekwondo federation currently applies the APIS ranking method to calculate the Olympic rankings, some limitations exist. **Objectives.** This study applies the PageRank model to Olympics Taekwondo rankings. **Methods.** The 2015-2018 World Taekwondo Grand Prix competition results for women's four weight classes (-49kg, -57kg, -67kg, +67kg) were used as research data, totaling 624 games. Excel and NetMiner programs were used to calculate the PageRank value, and the damping factor d was set to 0.15. **Results.** Player of People's Republic of China (CHN), WU, and JINGYU, was ranked as No. 1 in the case of -46kg Olympic women's weight class, and KIM, SO-HUI, player of Korea(KOR), and WONGPATTANKAKIT, PANIPAK, player of Thailand (THA), were ranked second. At -57kg, Great Britain (GBR)'s JONES, and JADE was ranked 1st, Turkey (TUR)'s TARTAR, Nauru (NRU) (2nd and Latvia (LAT)'s TARVIDA, INESE the 3rd. At -67kg, Ivory Coast (CIV)'s GBAGBI, RUTH was ranked 1st, KOR's OH, HYERI player, and TUR's TATAR, NUR. In the +67kg, CHN's ZHENG, SHUYIN ranked number 1, GBR's WALKDEN, BIANKA ranked second, and Poland (POL)'s KOWALCZUK, AKEKSANDRA ranked third. Second, as a result of comparing the validity of the PageRank model and the APIS model, the validity of the PageRank model was relatively higher in all four weight classes. **Conclusion.** The page ranking method was found to be more valid for measuring the ranking in Taekwondo competitions than the current APIS system, which we believe the page ranking method is suitable for measuring rankings in various sports events other than Taekwondo.

KEYWORDS: Taekwondo, PageRank, Ranking, Olympic, Accumulated Point Index System.

INTRODUCTION

In the sports sector, rankings are used as an index to evaluate the performance of teams or players. Most ranking calculations in sports events are based on the results of competitions and are used for the selection of athletes and the annual salary calculation of professional athletes (1).

The ranking calculation in the sports field is applied according to each sport's characteristics and competition rules, and the method is also applied in various ways. The ranking method for sports games includes ranking through records

(weight lifting, swimming, athletics, etc.), rankings based on wins and losses (soccer, basketball, baseball, etc.) (2-5) and rankings using accumulated points based on the results of competitions (badminton, tennis, Taekwondo), and others (3). In particular, in the case of Taekwondo events, which utilize the accumulative point index system (APIS) starting from the 2016 Rio Olympics, the top rankers (1st ~ 6th) are given the right to compete in the Olympics, making the rankings even more important concern for athletes and their coaches.

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Currently, the Taekwondo Olympic ranking system is based on the competition organized by the World Taekwondo (WT) to give points differentially in consideration of the rankings and the size of the competition (G1, G2, G4, G8, G12, G20). The system calculates the ranking by summing the points given to each athlete by weight class (6).

However, although the World Taekwondo federation currently applies the APIS ranking method to calculate the Olympic rankings, some limitations exist. In the case of the APIS ranking method, points are determined based on subjective opinions and according to the competition ranking and the competition level. Although points are decided by reflecting experts' opinions, there are no clear criteria (7, 8). In addition, the APIS ranking method calculates the ranking without considering the opponent's performance. Due to the nature of the Taekwondo game, if winning or losing is decided according to the opponent's performance level, players will get different rankings depending on the tournament draw. In other words, it would be more reasonable to judge the value of winning against the top 1 differently from winning against the top 10 (9).

To overcome these limitations, the PageRank model can be introduced. Recently the PageRank model has been proposed to calculate the ranking in the sports field (10). This can be complemented by not considering subjective point determination and opponent's performance, which were the limitations in calculating the Olympic Taekwondo rankings. PageRank, based on network theory, was introduced by Page and Brin in 1998 and is used as a Google search engine. Google determines how often to cite web pages when determining which pages to prioritize when providing search results (11-14).

Therefore, this study aims to calculate Olympic women's Taekwondo rankings by applying the PageRank model. In order to apply the PageRank model, the Olympic women's four weight classes (-49kg, -57kg, -67kg, +67kg) were calculated based on the results of the World Taekwondo Grand Prix organized by WT, and the validity of the model was verified. This suggests the ranking following the currently used Olympic Taekwondo ranking system, APIS, and compares it with the PageRank algorithm's rankings, confirming its validity.

MATERIALS AND METHODS

Research Data. This study used the results of the World Taekwondo Grand Prix provided by

the World Taekwondo (2018) to calculate the Olympic women's Taekwondo rankings using the PageRank algorithm. Specifically, in the World Taekwondo Grand Prix (2015 series 3~ 2018 series 1), women's four weight classes (-49kg, -57kg, -67kg, +67kg) were collected, totaling 624 games. The data used in this study are public data published on the World Taekwondo website.

Data Collection Procedure. For this study, researchers and two assistant researchers collected the World Grand Prix competition results using the data published on the World Taekwondo Federation's official website using Excel 2013. Specifically, the results of the 8 World Taekwondo Grand Prix competitions (2015 World Grand Prix series 3, final, 2016 World Grand Prix final, 2017 World Grand Prix series 1, series 2, series 3, final, 2018 World Grand Prix series 1) were collected according to the weight and the variables collected were the player's name, country and match results (win/lose).

Data Processing Method. This study aims to calculate the Olympic women's Taekwondo rankings by applying the PageRank model. MS Excel 2019 and NetMiner programs were used to calculate the women's Taekwondo PageRank value. In the case of the Excel program, the results of the matches provided by the World Taekwondo federation were used to reprocess the results into secondary data. Mode 1 is entered as a player x player matrix, with source set to losers and target set to winners. The NetMiner program was used to calculate the page rank value using the matrix data organized in mode 1. At this time, the damping factor d used in the page rank is set to 0.15. Damping factor d is interpreted as the probability that the Google engine is not satisfied with the page while searching and clicks on another page link (12), and in this study, it can be interpreted as the probability that the winning a player with excellent performance even if when the performance is low. PageRank generally sets the Damping factor d to 0.15 (15). In addition, to verify the validity of the PageRank model and APIS, classification accuracy was calculated using MS Excel 2019.

Also, the classification accuracy was calculated by calculating the binary classification table to confirm the validity according to the ranking model. The athletes with a 0% winning rate in each weight class were excluded from the validation. The basic assumptions for the validity test are as follows. If we assume that the rankings produced by PageRank are more valid than the APIS-based

rankings, then the rate of PageRank results should be relatively accurate to classify the actual results. If the higher ranking player wins against the lower player by the PageRank model in the Taekwondo competition, it can be interpreted as valid. Therefore, the validity was verified in this study through the following (Formula 1).

Accuracy = (TP+TN) / (TP+FN+FP+TN)
(Formula 1)

RESULTS

Comparing Olympic women's Taekwondo rankings using PageRank

Women's Taekwondo -46kg Rankings Comparison (PageRank and APIS)

(Table 1) is the result of calculating the top 10 Olympic women's Taekwondo -46kg rankings

using the PageRank model. As a result, WU, JINGYU (PR: 0.0444) of CHN was ranked 1st, KIM, SO-HUI (PR: 0.0430) of KOR ranked 2nd, and 3rd, WONGPATTANAKIT, PANIPAK (PR: 0.0373) of THA. As a result of comparing PageRank and APIS it was confirmed that the ranking difference was largely up to 17 levels in the players from 1st to 10th. In addition, the second-ranked KOR player had a 77.3% winning rate (out of 22 games, 17 wins, and five losses), while the third-place THA player had an 84.6% winning rate (out of 13 games, 11 wins, and two losses). This result can be interpreted as considering the opponent's ability which is the advantage of the PageRank model, despite the low winning rate.

Table 1. Women's Taekwondo Top 10 Olympic Rankings of -49kg Using PageRank

Name of Player	Country	PR	PRrank	APIS
WU, INJGYU	CHN	0.0444	1	17
KIM, SO-HUI	KOR	0.0430	2	2
WONGPATTANAKIT, PANIPAK	THA	0.0373	3	1
HA, MIN-AH	KOR	0.0246	4	15
TANG SING, IRIS	BRA	0.0180	5	6
IGUMENOVA, SVETLANA	RUS	0.0174	6	21
THI KIM TUYEN, TRUONG	VIE	0.0171	7	10
YILDIRIM, RUKIYE	TUR	0.0162	8	4
STANKOVIC, VANJA	SRB	0.0156	9	8
C. MADDOCK	GBR	0.0152	10	27

PR: PageRank value, PRrank: PageRank, APIS: accumulative point index system rank, CHN: China, KOR: Korea, THA: Thailand, BRA: Brazil, RUS: Russian, VIE: Vietnam, TUR: Turkey, SRB: Serbia, GBR: Great Britain

Table 2. Women's Taekwondo Top 10 Olympic Rankings of -57kg Using PageRank

Name of Player	Country	PR	PRrank	APIS
JONES, JADE	GBR	0.0789	1	1
ILGUN, HATICE KUBRA	TUR	0.0679	2	4
TARVID, INESE	LAT	0.0619	3	20
CALVO GOMEZ, EVA	ESP	0.596	4	7
MALAK, HEDAYA	EGY	0.0563	5	18
LEE, AH-REUM	KOR	0.0468	6	2
ASEMANI, RAHELEH	BEL	0.0222	7	12
KIM, EKATERINA	RUS	0.0220	8	21
BOOTH, RACHELLE	GBR	0.0206	9	22
PARK, SKYLAR	CAN	0.0170	10	10

PR: PageRank value, PRrank: PageRank, APIS: accumulative point index system rank, GBR: Great Britain, TUR: Turkey, LAT: Latvia, ESP: Spain, KOR: Korea, BEL: Belgium, RUS: Russian, CAN: Canada

1.2 Women's Taekwondo -57kg Rankings Comparison (PageRank and APIS)

(Table 2) is the result of calculating the top 10 Olympic women's Taekwondo -57kg rankings using the PageRank model. As a result, JONES, JADE (PR: 0.0789) of GBR was ranked 1st, ILGUN, HATICE KUBRA (PR: 0.0679) of TUR ranked 2nd, and 3rd, TARVIDA, UNESE (PR: 0.0619) of LAT. As a result of comparing PageRank and APIS, it was confirmed that the ranking difference was mainly up to 17 levels in

the players from 1st to 10th. In addition, although the third-ranked LAT player had a relatively low winning rate of 42.9% (out of 7 games, three wins, and four losses), the high ranking in PR is by considering the opponent's ability which is the advantage of the PageRank model. In other words, CRO player would have won or lost against a relatively excellently performing player.

1.3 Women's Taekwondo -67kg Rankings Comparison (PageRank and APIS)

(Table 3) is the result of calculating the top 10 Olympic women's Taekwondo -67kg rankings using the PageRank model. As a result, GBAGBI, RUTH (PR: 0.0538) of CIV was ranked 1st, OH, HYERI (PR: 0.0501) of KOR ranked 2nd, and 3rd, TATAR, NUR (PR: 0.0492) of TUR. As a result of comparing PageRank and APIS, it was confirmed that the ranking difference was mainly

up to 22 levels in the players from 1st to 10th. In addition, the CIV player who ranked 1st in PageRank had a winning rate of 75% (out of 16 games, 12 wins, and four losses), KOR player who ranked second had a winning rate of 72.7% (out of 22 games, 16 wins, and six losses) and TUR player who ranked third had 71.2% (out of 21 games, 15 wins, and six losses).

Table 3. Women's Taekwondo Top 10 Olympic Rankings of -67kg using PageRank

Name of Player	Country	PR	PRrank	APIS
GBAGBI, RUTH	CIV	0.0539	1	3
OH, HAERI	KOR	0.0501	2	1
TATAR, NUR	TUR	0.0492	3	2
GUO, YUNFEI	CHN	0.0449	4	6
NIARE, HABY	FRA	0.0384	5	8
CHUANG, CHIA CHIA	TPE	0.0283	6	9
MENGYU, ZHANG	CHN	0.0275	7	18
WILLIAMS, LAUREN	GBR	0.0268	8	5
WIET HENIN, MAGDA	FRA	0.0221	9	13
ZHANG, HUA	CHN	0.0149	10	32

PR: PageRank value, PRrank: PageRank, APIS: accumulative point index system rank, CIV: Ivory coast, KOR: Korea, TUR: Turkey, CHN: China, FRA: France, TPE: Chinese Taipei, GBR: Great Britain

Table 4. Women's Taekwondo Top 10 Olympic Rankings of +67kg Using PageRank

Name of Player	Country	PR	PRrank	APIS
ZHENG, SHUYIN	CHN	0.0804	1	2
WALKDEN, BIANCA	GBR	0.0785	2	1
KOWALCZUK, ALEKSANDRA	POL	0.0729	3	7
LEE, DA-BIN	KOR	0.0387	4	11
BANDIC, MILICA	SRB	0.0379	5	3
KUS, NAFA	TUR	0.0293	6	6
AN, SAEBOM	KOR	0.0234	7	12
IVANOVA, OLGA	RUS	0.0204	8	15
EPANGUE, GWLADYS	FRA	0.0177	9	20
ESPINOZA, MARIA	MEX	0.0159	10	65

PR: PageRank value, PRrank: PageRank, APIS: accumulative point index system rank, CHN: China, GBR: Great Britain, POL: Poland, KOR: Korea, SRB: Serbia, TUR: Turkey, RUS: Russian, FRA: France, MEX: Mexico

Table 5. Example of Validity Verification by Binary Classification Table (Women's - 49kg)

	Actual Match Results		
	Win Match	Defeat Match	Total
PageRank Model			
High Ranking Player	111 (TP)	32 (FP)	144
Low Ranking Player	32 (FN)	111 (TN)	144
Total	144	144	288
Accuracy		0.770	
	Actual Match Results		
	Win Match	Defeat Match	Total
A P I S Model			
High Ranking Player	102 (TP)	42 (FP)	144
Low Ranking player	42 (FN)	102 (TN)	144
Total	144	144	288
Accuracy		0.708	

* APIS: accumulative point index system rank

1.4 Women's Taekwondo +67kg Rankings Comparison (PageRank and APIS). (Table 4) is the result of calculating the top 10 Olympic

women's Taekwondo +67kg rankings using the PageRank model. As a result, ZHENG, SHUYIN (PR: 0.0804) of CHN was ranked 1st,

WALKDEN, BIANCA (PR: 0.0785) of GBR ranked 2nd, and 3rd, KOWALCZUK, ALEKSANDRA (PR: 0.0729) of POL. As a result of comparing PageRank and APIS, it was confirmed that the ranking difference was mainly up to 11 levels in the players from 1st to 10th. In addition, the CHN player who ranked 1st in PageRank had a winning rate of 73.9% (out of 23 games, 17 wins, and six losses), GBR player who ranked second had a winning rate of 88.4% (out of 26 games, 23 wins, and three losses) and POL player who ranked third had 64.7% (out of 17 games, 11 wins, and six losses). Result of validation according to ranking model (PageRank and APIS). (Table 5) shows the results of validating the women's Taekwondo -46kg rankings model. This is a binary classification table and classification accuracy that reflects the actual results of PageRank and APIS. As a result, when the PageRank model is applied in the case of -49kg class, 111 players achieve a higher ranking and the number of APIS cases is calculated less than 102 times. In the case of a player with a low ranking, the PageRank model (32 times) was lower than the APIS model (42 times); as a result of comparing the classification accuracy, the validity index, the PageRank model (acc: 0.770) was calculated higher than that of the APIS model (acc: 0.708). At -57kg, PageRank .578, APIS .562 and -67kg were PageRank .697, APIS .625, and +67kg were PageRank .721 and APIS .663.

DISCUSSION

In the Taekwondo competition, the Olympic rankings provide an index for evaluating the player's performance and give Olympic automatic participation right (16). As ranking has been emphasized more than in the past, limitations on the APIS ranking method are emerging. In addition, since the APIS method is applied to other sports, this situation presents the same problem in ranking other sports. Therefore, the PageRank model is suggested as an alternative to the ranking calculations (2). Therefore, in this study, we applied the PageRank model to calculate the Olympic women's rankings and confirmed the difference and validity of the existing ranking calculation method (APIS).

First, the women's Olympics -46kg weight class differed in the rankings calculated from the two ranking models. In the case of the CHN athlete who ranked first in PageRank, we can see that she is ranked 17th in APIS. The interesting

thing about this study is that there are 16 stages of difference depending on the ranking method, and at the same time, the eligibility for automatic participation is different. As a result, it was confirmed that the athletes' right to participate changed according to the Olympic ranking method, which acts as a variable that affects the individual and the association and the country. In addition, 10 athletes (-46kg: 3 players, -57kg: 3players, -67kg: 2players, +67kg: 2players), including women's -46kg, will be eligible for Olympic for automatic participation depending on the ranking method. It appears that the importance of the ranking method will have no choice but to emphasize it even more.

Second, as a result of calculating the classification accuracy to verify the validity of the two methods in calculating the Olympic Taekwondo rankings, the PageRank model was valid for all four weight classes. As a result of comparing with the actual game results, the classification rate (correct classification, misclassification) was higher than the APIS model. Previous studies have argued that the PageRank model is more suitable than the APIS method, supporting the result of the study (8, 17). However, there are limitations in determining the validity of the two ranking models in one index, and it is necessary to verify the validity of the ranking through various methods.

On the other hand, as the importance of calculating the Olympic rankings in the Taekwondo field is increasing, this study proposed the PageRank model to compensate for the problem of ranking. However, the PageRank model applied in this study has the disadvantage of requiring complex mathematical calculations (18). Of course, the mathematical calculations can be solved by an automated system in the field, but it is difficult to predict the rankings because the players or the coaches cannot check the process of calculating the rankings. Nevertheless, this study does not have much meaning in considering opponents' performance in calculating the Olympic Taekwondo rankings, which is not subjective. As interest in fairness and objectivity is increasing in many sports fields, we believe that Taekwondo can be the basis for globalization and maintaining it in the Olympic game.

Finally, in the sports field, various ranking methods are applied in consideration of the characteristics of each sport (6, 11, 15, 18, 19), and there is indeed a considerable interest in the

selection of ranking methods. Among the ranking methods, PageRank has a disadvantage because it is difficult to calculate. However, it does have a theoretically broad scale (9, 20, 21). Therefore, if the PageRank algorithm method is applied to various sports other than Taekwondo, it will be possible to calculate more good rankings. Therefore, it is hoped that further research will provide additional evidence that the PageRank model is a suitable method for calculating rankings in sporting events.

CONCLUSION

This study aims to calculate the Olympic women's Taekwondo rankings by applying the PageRank model. The conclusion of this study is as follows. First, WU, JINGYU of CHN was ranked 1st, KIM, SOHUI of Korea 2nd, and WONGPATTANAKIT, PANIPAK of THA 3rd. At -57kg, GBR's JONES, JADE was ranked 1st, 2nd place was ILGUIN HATICE KUBRA of

TUR, 3rd was TARVIDA, INESE of LAT. At -67kg, CIV's GBAGBI, RUTH was ranked first, OH, HYERI of KOR second, and TATAR, NUR of TUR 3rd.

At +67kg, CHN's ZHENG, SHUYIN was ranked 1st, 2nd place was WALKDEN, BIANCA of GBR and 3rd place KOWALCZUK, ALEKSANDRA of POL. Second, as a result of comparing the validity of the PageRank model and the APIS model, the validity of the PageRank model was relatively high in all four weight classes. The subsequent study, it will be helpful to include information on competition's weights and opponent players' ranking in the practical field.

APPLICABLE REMARKS

- Based on the results of this study, it is believed that it can be used as meaningful information for calculating the Taekwondo rankings.
- This study could be used more fairly in determining the rankings of Taekwondo athletes.

REFERENCES

1. Motegi S, Masuda N. A network-based dynamical ranking system for competitive sports. *Sci Rep.* 2012;2:904. doi: 10.1038/srep00904 pmid: 23226590
2. Park J, Newman ME. A network-based ranking system for US college football. *Journal of Statistical Mechanics. Theory and Experiment*2005.
3. Moon WJ, Park ME, Lee TS. Analyzing the performance of Rio Olympic athletes. *Sport Sci.* 2018:71-79. doi: 10.46394/ISS.35.2.8
4. Jung KC, Yang DS. An Analysis on the Scoring Patterns According to Type of Game Tactics in World-class Taekwondo Players. *Korean Societ Sport Sci.* 2016:1303-1315.
5. Choi YL, Lee YK. The Relationship among Mentoring, Training attitude and recognized Athletic performance of Taekwondo Athletics. *Korean Societ Sport Sci.* 2016:965-974.
6. Jo EH, Park JH, Choi CH. A PageRank Algorithm for the Rankings of Korea Badminton Players. *J Korean Data Anal Soc.* 2017:373-382. doi: 10.37727/jkdas.2018.20.1.373
7. World Taekwondo. 2020. Available from: <http://m.worldtaekwondo.org/>.
8. Barrow D, Drayer I, Elliott P, Gaut G, Osting B. Ranking rankings: an empirical comparison of the predictive power of sports ranking methods. *J Quantitative Anal Sport.* 2013:187-202. doi: 10.1515/jqas-2013-0013
9. Deng W, Li W, Cai X, Bulou A, Wang QA. Universal scaling in sports ranking. *New J Physic.* 2012:093038. doi: 10.1088/1367-2630/14/9/093038
10. Kim EH, Jeon MS. Proposal for implementation of a ranking model for Olympic Taekwondo competitions using PageRank. *Int J Performance Anal Sport.* 2019:227-235. doi: 10.1080/24748668.2019.1586506
11. Yoon JW, Park JH. Historical ranking of vault players in artistic gymnastics using PageRank algorithm. *Korean J Sport Sci.* 2017:506-516. doi: 10.24985/kjss.2017.28.2.506
12. Page L, Brin S, Motwani R, Winograd T. The PageRank citation ranking: Bringing order to the web1999.
13. Beggs CB, Shepherd SJ, Emmonds S, Jones B. A novel application of PageRank and user preference algorithms for assessing the relative performance of track athletes in competition. *PLoS One.* 2017;12(6):e0178458. doi: 10.1371/journal.pone.0178458 pmid: 28575009
14. Brown S. A PageRank model for player performance assessment in basketball, soccer and hockey. arXiv preprint arXiv2017. 1704.00583 p.

15. Boldi P, Santini M, Vigna S. PageRank as a function of the damping factor. In Proceedings of the 14th international conference on World Wide Web 2005.
16. Kim SH, JO WS. An Investigation of Taekwondo Olympic Medalists' Trust of Coach. *Korean Soc Sport Sci.* 2020:495-512. doi: 10.35159/kjss.2020.02.29.1.495
17. Kim BS. Development of Taekwondo ranking model based on Google PageRank algorithm. *Int J Pure Appl Mathemat.* 2018:1267-1278.
18. Rojas-Mora J, Chávez-Bustamante F, del Río-Andrade J, Medina-Valdebenito N. A methodology for the analysis of soccer matches based on pagerank centrality. In Sports Management as an Emerging Economic Activity 2017.
19. Park Y. An Unplugged Activity to Understand the PageRank Algorithm. *J Korean Associat Inform Educat.* 2018:409-417. doi: 10.14352/jkaie.2018.22.4.409
20. Kim HS, Park JH, Jo EH, Choi CH. The Most Successful Team in AFC Asian Cup History : Country Rankings Using PageRank Algorithms. Korean Society of Measurement and Evaluation for Physical Education and Sports Science 2019.
21. Lazova V, Basnarkov L. PageRank approach to ranking national football teams. arXiv preprint arXiv:2015.