JKSCI

한국컴퓨터정보학회논문지
Journal of The Korea Society of Computer and Information
Vol. 25 No. 7, pp. 103-111, July 2020
https://doi.org/10.9708/jksci.2020.25.07.103

The identification of optimal data range for the discrimination between won and lost

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[Abstract]

Performance indicators have often investigated and developed in order to identify foundational elements and factors for an enhancement of performance in sports. In order to identify the valid performance indicators it is important that the indicators used within a performance analysis system discriminate between the winning and losing performances within a match (Hughes and Bartlett, 2002). However, the performance indicators proposed in research studies on basketball performance have not been used for real-time analysis and feedback within a coaching context. Such real-time support for the coach and players has been described within research on other sports (Choi et al., 2004; O'Donoghue, 2001; Palmer et al., 1997). Within the process of real-time feedback, the identification of relevant performance indicators that distinguish winning and losing performances should be the first stage of the development of a real-time analysis system. Therefore, this study investigated the differences between winning and losing teams in terms of a set of performance indicators gathered during the analysis of 10 English National Basketball League matches. Winning and losing teams were compared using whole match data (N=10) as well as individual quarters (N=40). A series of Wilcoxon Signed Ranks tests was used to identify the relevant performance indicators that discriminate between winning and losing performers within whole matches and individual quarters. The tests found that 3 point shots made ($p<0.05$) and Assists ($p<0.05$) were significantly different between winning and losing teams within matches. However, 2 point shots made ($p<0.05$), 2 point shots attempted ($P<0.05$), percentages of 2 point shots scored ($p<0.05$), 3 point shots made ($p<0.05$), Defensive Rebounds ($p<0.05$) and Assists ($p<0.05$) were significantly different between winning and losing performance within quarters. The analysis task should be based on relevant performance indicators which explain the current performances to performance analysts and coaches. Within a real-time analysis and feedback scenario, this will have the additional benefit of supporting a decision based on immediate performance within the most recent quarter. Consequently, the real-time analysis system would use performance indicators which have the property of construct validity to support the decisions of the coach.

▸ **Key words**: discrimination of winning, performance indicators, statistics in sports, a real-time analysis

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• Received: 2020. 07. 13, Revised: 2020. 07. 28, Accepted: 2020. 07. 29.

http://www.ksci.re.kr pISSN:1598-849X | eISSN:2383-9945

[요 약]

성과를 나타내는 지표는 스포츠 성과 향상을 나타내는 기본 요소를 식별하기 위해 개발되었다. 유효한 성과 지표를 식별하려면 성과 분석 시스템 내에서 사용 된 지표가 경기 내에서 성과의 승패를 구별하는 것이 매우 중요하다고 할 수 있다. (Hughes and Bartlett, 2002). 그러나 농구 성과에 관한 연구에서는 제안된 성과와 지표는 코치 및 선수의 상황에 따라 실시간 분석 및 피드백이 사용되지 않고 있다는 점이다. 코치 및 선수에 대한 이러한 실시간 지원은 다른 스포츠에 대한 연구에서도 설명되고 있다. (Choi et al., 2004; O'Donoghue, 2001; Palmer et al., 1997).

실시간 피드백 프로세스 내에서 성과와 손실을 구분하는 관련성과 지표를 식별하는 것이 실시간 분석 시스템 개발의 첫 단계가 되어야 한다. 따라서 이 연구는 10 개의 잉글랜드 내셔널 농구 리그 경기를 분석하는 동안 수집 된 성과 지표 세트 측면에서 팀의 승패와 패배의 차이점을 조사하였다. 승리와 패배 팀은 전체 경기 데이터 (N=10)와 개별 쿼터 (N=40)를 사용하여 비교되었다. 일련의 Wilcoxon Signed Ranks 테스트를 사용하여 전체 경기와 개별 쿼터 내에서 성과를 낸 사람과 잃는 사람을 구별하는 관련성과 지표를 식별하였다.

테스트 결과 3점 ($p<0.05$)과 어시스트 ($p<0.05$)는 경기 내 팀의 승패에서 크게 차이가 있다고 할 수 있다. 그러나 2점 슛 ($p <0.05$), 2점 샷 시도 ($P <0.05$), 2 점 샷의 백분율 ($p <0.05$), 3 점 샷 ($p <0.05$), 수비 리바운드 ($p <0.05$)) 및 지원 ($p <0.05$)은 분기 내 실적의 승패에서 크게 다르게 나타나고 있다.

위와 같은 분석 작업은 성과분석에 따라 코치에게 현재 성과를 설명하는 관련성과 지표를 기반으로 해야 한다. 실시간 분석 및 피드백 시나리오 내에서 가장 최근 분기 내에서 즉각적인 성과를 기반으로 의사 결정을 지원하는 추가 이점이 있다.

결과적으로, 실시간 분석 시스템은 코치의 결정을 뒷받침하기 위해 필요하며 유효성 특성을 갖는 성능 지표를 사용한다.

▸ **주제어**: 승리의 차이, 성과 지표, 스포츠 통계, 실시간 분석

Ⅰ. Introduction

Performance indicators have improved performance analysis systems in recent years. Performance indicators have been developed to identify the fundamental elements of performance in sports. <Definition of Performance Indicators>. The identification of the performance indicators in sports was proposed as a first step of the analysis. Performance indicators should discriminate successful performances in order to be valid (Hughes and Bartlett, 2002). Thus, performance indicators have been categorized and sub-categorized with scientific and critical aspects for different sports. Within the field of performance analysis of sport, the consideration of discrimination between winning and losing teams has been utilized to identify the key performance indicators in particular sports such as football (Choi et al., 2006a), badminton (Blomqvist et al., 1998; Hong and Tong, 2000) and basketball (Tina, 1998; Evangelos et al., 2005; Tavares and Gomes, 2003). Especially, the selection of valid indicators for the applications of performance analysis techniques has also considered within the analysts or coaches' perspectives. The performance indicators (Hughes and Bartlett, 2002) in the field of performance analysis of sport are valid elements to explain the performances of successful activities and events in matches. Thus, the outcome data collected by performance indicators (Hughes & Bartlett, 2002) are rationally useful for coaches in order to evaluate the performances and to conduct the further training plan for athletes.

In last year, the performance indicators have selected and utilized in the analysis of

performances in order to enhance the performances of sports (Hughes and Franks, 2004). The performance indicators used in previous research of basketball, however, have not been used for real-time analysis and feedback. The possibility and essentiality of real-time analysis using performance analysis techniques in order to support coaches and players in matches have already been presented in other sports such as soccer (Choi et al., 2004) and netball (Palmer et al., 1997). Within the process of real-time feedback, the identification of the valid performance indicators is an essential stage in the development of performance analysis systems. Therefore, the stage of identification of valid performance indicators should be the first stage of developing real-time analysis systems (Hughes & Bartlett, 2004). Previous studies have used whole match data to discriminate between winning and losing performances in the search for valid performance indicators. Often performance fluctuates within matches with competing sides enjoying successful and unsuccessful periods.

The performance indicators selected have traditionally been from the whole matches' data which were including the data in separated time scale such as the quarter data in basketball. In the whole data of matches, the winners and losers might be found in the separated data that it is not perfectly presented the valid performance indicators within the data. For instance, the match winner and loser have the unstable time periods in the quarter or the match in basketball. That is shown that the winner in the match performed not perfectly that the losers of the match winner during the game playing might be existed. In tennis, particularly, the performance indicators from whole matches would be not always reflected to the whole match performances and the coach need to identify different areas of the match at different points of the game that need to be addressed. Therefore, the consideration of valid performance indicators within the separated time scales such as sets in tennis is needed in order to discriminate the winning performances of the match. The identification of valid performance indictors within the valid sets of data, perhaps, is on a step in order to figure the construct validity of performance indicators out.

The main aim of this study, therefore, is to compare the performance indicators identified when using whole match data and data sets from parts of matches in two different characteristics of games, Team and individual sports such as basketball and tennis. It was not only the purpose of the study that the discussions on differences found have concerned.

II. Methods

1. Subjects

The basketball and men's single tennis were considered to identify the optimal data range for the discrimination between won and lost in this study. For the basketball data, Ten English league basketball matches in the 2005-2006 season were selected randomly for analysis providing a game data set (N=20) and a quarter data set (N=80). For the tennis data, the results of tennis matches (n=126) and the results of set in the matches were used basing on the official web site of Wimbledon Tennis championship (IBM Corp., 2005). However, 2 matches were missing that they were not included in the study.

2. Definitions of 'won' and 'lost'

First of all, the winning performances within the game data were defined using the final results to discriminate between the winning and losing performances in the Basketball. Within the quarter data sets, the winning and losing performances were discriminated using the scores within those quarters.

It was same to the Tennis data that the won and lost defined based on the final results of matches. The won and lost in the set of match, however, defined differently based on the results of set in

the match. Table 1 is shown the notations of the definitions used in the study.

Table 1. The notations of the definitions

		Won	Lost
Basketball	Match won	MWW	MWL
	Match lost	MLW	MLL
	Quarter won	QWW	QWL
	Quarter lost	QLW	QLL
Tennis	Game won	GWW	GWL
	Game lost	GLW	GLL
	Set won	SWW	SWL
	Set lost	SLW	SLL

3. Variables used as the performance indicators

The physical exercise program respected the general guidelines proposed by the American College of Sports Medicine (ACSM, 2006) and consisted of three times a week sessions of 50 minutes, divided into 15 minutes of warm-up, 20min aerobic, strength and flexibility exercises, and 15min relaxation exercises. The exercise intensity sessions were between 50 and 60% of maximal heart rate and were aimed at improving aerobic capacity, upper and lower stretching and strength training from sets of callisthenic exercises.

Totally, 16 variables in Basketball and 12 variables were chosen as shown in Table 2.

Table 2. Variables used in the study

No.	Basketball	Tennis
1	2P shots-made	No. Participations
2	2P shots-miss	World Rankings
3	% 2P shots success	% Successful Serves
4	3P shots-made	Aces
5	3P shots-miss	Double Faults
6	% 3P shots success	Unforced errors
7	FT shots-made	% 1st serves
8	FT shots-attempts	% 2nd serves
9	% FT shots success	Winners
10	Offensive Rebound	Received points
11	Defensive Rebound	Break points won
12	Ratio of OR (%)	% of net approaches
13	Personal Fouls	
14	Assists	
15	Turnovers	
16	Steals	

4. Statistics

The Wilcoxon Signed Ranks tests, a non-parametric statistics, were used to discriminate between the won and lost performances within each sport that the findings were accepted where the p-value was less than 0.05 statistically. After the statistical comparisons in each sport, the results of the Wilcoxon Signed Ranks tests were discussed.

III. Results

1. Descriptive analysis of the data

This study was to compare the performance indicators identified within the discrimination between won and lost. The subject used in this study shown that there were different data characteristics based on the concept of 'winning' and 'losing' performance. Table 3 is shown the description of the subjects used. Accordingly, the won and lost in the game, defined as 'winner' and 'loser' in common sense, had 100% 'winning performance' or 'losing performance' within the matches in basketball and games in tennis.

Table 3. The description of the subjects used

		Won	Lost
Basketball	Match won	20	0
	Match lost	0	20
	Quarter won	56	24
	Quarter lost	24	56
Tennis	Game won	126	0
	Game lost	0	126
	Set won	288	158
	Set lost	158	288

The concept of the 'winning' and 'losing' performance based on the separated data range such as quarters in basketball and sets in tennis brought that there were 'winning' performance for lost, also 'losing' performance for won.

Table 4. The statistical comparisons in Basketball

	Match data		Quarter data	
	Z	Sig.	Z	Sig.
2P shots-made	-1.89	.06	-4.70 a	.00
2P shots-miss	-1.43	.15	-2.74 a	.01
% 2P shots success	-0.36	.72	-3.47 a	.00
3P shots-made	-2.13 a	.03	-2.97 a	.00
3P shots-miss	-0.46	.64	-2.06 a	.04
% 3P shots success	-0.25	.80	-0.08	.94
FT shots-made	-0.36	.72	-0.10	.92
FT shots-attempts	-0.42	.68	-0.86	.39
% FT shots success	-1.60	.11	-1.52	.13
Offensive Rebound	-1.01	.31	-1.36	.18
Defensive Rebound	-0.77	.44	-2.12 a	.03
Ratio of OR (%)	-1.58	.11	-0.67	.50
Personal Fouls	-0.46	.65	-0.58	.56
Assists	-2.13 a	.03	-4.20 a	.00
Turnovers	-1.43	.15	-0.75	.45
Steals	-1.48	.14	-0.80	.42

Note: 'a' indicated where p-value were less than .05

2. The results of comparisons in Basketball

The study was to compare the differences found within the statistical comparisons between won and lost when the data range was different, but same subjects in basketball. <Table 4> shown that the results of the Wilcoxon Signed Ranks tests performed on the performance indicators within the match data and the quarter data in basketball.

The 'winning' and 'losing' performances were only distinguished by 2 performance indicators within the match data set in despite of 7 performance indicators within the quarter data. The variables, the significant differences ($p<.05$) found, were 3P shots-made and assist within the match data. On the other hand, the 2P shots-made, 2P shots-miss, % 2P shots success, 3P shots-made, 3P shots-miss, defensive rebound and assists were significant differences ($p<.05$) within the quarter data. Thus, there were 5 additional performance indicators that discriminate between winning and losing performances when recognizing the fluctuating form of teams within matches by analysing individual quarters rather than whole matches.

3. The results of comparisons in Tennis

The findings on the comparison between game data and set data in tennis were also shown the different figures within the statistical comparison. <Table 5> shown that the results of the Wilcoxon Signed Ranks tests performed on the performance indicators within the game data and the set data in tennis.

The significant differences between the winning and losing performances were found that the no. participations to the Wimbledon tennis competition ($z=-1.68$, $p=.09$) and % of successful serves ($z=-0.57$, $p=.57$) were only the variables not significantly different within the Wilcoxon Signed Ranks test in the game data. On the other hand, all variables found as the significant differences within the set's data in order to discriminate the won and lost in tennis. Additionally, the double faults in game data, no. participations and % successful serves in set data were shown the significant differences less than .05 confident level. The other variables such as world ranks, aces, unforced errors, % 1st serves, % 2nd serves, winners, received points, break points won and % of net approaches were shown significant differences less than .01 of confident level.

Table 5. The statistical comparisons in Tennis

	Game data		Set data	
	Z	Sig.	Z	Sig.
No. Participations	-1.68	.09	-2.19a	.03
World Rankings	-4.88a	.00	-5.76a	.00
% Successful Serves	-0.57	.57	-2.77a	.01
Aces	-5.38a	.00	-7.82a	.00
Double Faults	-2.19a	.03	-4.33a	.00
Unforced errors	-4.38a	.00	-8.21a	.00
% 1st serves	-8.53a	.00	-14.1a	.00
% 2nd serves	-7.39a	.00	-12.0a	.00
Winners	-6.73a	.00	-11.14a	.00
Received points	-9.39a	.00	-16.48a	.00
Break points won	-6.04a	.00	-12.67a	.00
% of net approaches	-5.53a	.00	-7.46a	.00

Note: 'a' indicated where p-value were less than .05

IV. Discussion

The significant differences between the winning and losing performances in the Wilcoxon Signed Ranks test have often used in order to determine the data statistically and to identify the key performance indicators (Choi, 2004; Choi et al., 2006c; Choi et al., 2006b; O'Donoghue, 1998). Especially, to find the key indicators of performances has emphasized in previous researches (Tina, 1998; Hughes & Bartlett, 2002). The previous method to find the key indicators of performances was the collected and determined data based on the whole matches. The difference of the key indicators between different data sets, however, has found that the key performance has not found in the whole data such as the percentage of successful serves was found in the individual data. Perhaps, the data range of subjects (Choi et al., 2006c; Choi et al., 2006b) would influence upon the results in order to identify the key performance indicators which would be used to further training plan by coaches.

Within the study about the analysis of passing sequences, shots and goals (Hughes & Franks, 2005), the possession has used to terminate the actual values of performances into the profiling. In other words, the sequences would address the nationalized structure of evaluation to performance in the field of performance analysis of sport. The unit of time concerned in the analysis, therefore, is necessary that the consideration of performance in time sequences would explain the winning and losing performance reasonably. The selection of key performance indicators(Choi et al., 2006b) in the researches, in addition, has already emphasized the applications of the key performance indicators for real-time analysis. The applications of the key performance indicators in real-time analysis (Choi et al., 2006b) would be utilized to the real-time feedback in a match that the valid performance indicators are able to be used to identify the key performances in real-time.

Previous research into performance indicators in basketball has utilized the final results of games in order to find key elements of performances that the match outcome is associated with(Silva, 1998; Cruz & Tavares, 1998; Mendes & Janeira, 1998; Silva, 1998; Tina, 1998; Tavares & Gomes, 2003; Evangelos et al., 2005; Mexas et al., 2005). The data analysed by the systems have helped coaches make decisions on particular situations within matches. As a purpose of real-time analysis, however, the data analysed in lapsed-time, such as that of the match data in basketball, has limits in providing valid information of characteristics of the winning and losing performances. In other words, the selection of valid performance indicators for real-time analysis has to be concerned with data sets that recognize the fluctuating form of performance within matches,

such as the quarter data within the current basketball example. Performance analysis using valid performance indicators within real-time analysis systems, consequently, would enhance decision making by coaches in basketball.

In tennis games, it might be also similar with the basketball that the key elements of performances would be able to be used for the enhancement of performances within the winning and losing situations. Within the study relevant to the identification of performance indicators in tennis(Choi, Hughes, O'Donoghue & Takahashi, 2007; the performance indicators were selected without any consideration of data range or size. As the results of this study shown, it would be same concepts of consideration which data is suitable for the real-time analysis. Additionally, it is not only for the real-time analysis that the potentiality of applicable indicators into the discrimination between winning and losing. Thus, the game data in tennis, perhaps, is expressed the overall outcome rather than the characteristics of winning and losing in a small range of data such as sets in tennis.

The interesting findings were that numbers of significant differences found in the comparisons of different range of data were existed depending on the sport.

Ⅴ. Conclusion

The valid performance indicators found between winning and losing performances in the whole data set are total numbers of participations to Wimbledon tennis championship, world ranks of players, aces, double faults, unforced errors, % of successful 1st serves, % of successful 2nd serves, winners, received points breaks and % of net approaches($p<0.05$). The valid performance indicators found in individual data are the indicators including the % of successful serves ($p<0.05$). Thus, all indicators have found as the valid performance indicators in this study. For the further researches, the identifications of efficient usages to the coaching process in real-time (Choi et al., 2004; Choi et al., 2006c)are required.

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