

## DEVELOPMENT OF STATISTICAL DATA INDEX FOR EVALUATING THE TACTICAL ASPECTS OF ATTACK AND DEFENSE IN HANDBALL

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### Abstract

The purpose of this study was to develop the useful statistical data indexes to evaluate the team performance of attack and defense during handball match. The subject of analysis in this study were 216 matches of Japan Handball League in 2017-2018 and 2018-2019 seasons and 145 matches of Handball-Bundesliga in 2018-2019 season. We calculated the ratio of goal, free throw, turnover against the possessions to make an index of expected goal (xG), expected received free throw (xRTF) and expected turnover (xTO) in attack phase. Similar, expected opposing goal (xL), expected taken free throw (xTTF) and expected opposing turnover (OppxTO) were calculated in defense phase. Also, shot efficiency (%G) and opposing shot efficiency (%L) were calculated. As a results of multiple regression analysis, we found that %G, xTO and xRTF in attack phase and %L, OppxTO and xTTF in defense phase were important variables to evaluate the team performance. In conclusion, %G, xRTF and xTO in the attack phase and %L, xTTF and OppxTO in the defense phase are important indexes for evaluating the team performance and these are very useful statistical indexes for real-time analysis during the match.

*Key words; quantitative analysis, quality analysis*

### Introduction

Match analysis of sports can help coach decisions and improve team performance. It is very important to use reliable performance indicators for match analysis. In previous study, we calculated the ratio (xG) of number of goal scores against the number of possessions as an attack index and the ratio (xL) of number of opposing goal scores against the number of opposing possessions as a defense index (Ichimura et al. 2017). The required values of the xG and xL to qualify the preliminary round in men's world handball competitions was calculated using ROC curve analysis.

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Therefore, we believe that xG and xL are very powerful indexes for evaluating the team performance of attack and defense. However, xG and xL cannot clarify the details of their team performance because xG and xL include all attacking and defense information such as turnover and shot efficiency.

Thus, we have to search the more detailed indexes to evaluate the more detailed team performance. Thus, the purpose of this study was to develop the useful statistical data indexes to evaluate the team performance of attack and defense during handball match, based on terminate of attack or defense phase.

## Methods

### Data collection

The subject of analysis in this study were all matches (216 matches) of Japan Handball League (JHL) in two seasons of 2017-2018 and 2018-2019 and 145 matches of all matches (306 matches) of Handball-Bundesliga (HBL) in 2018-2019 season.

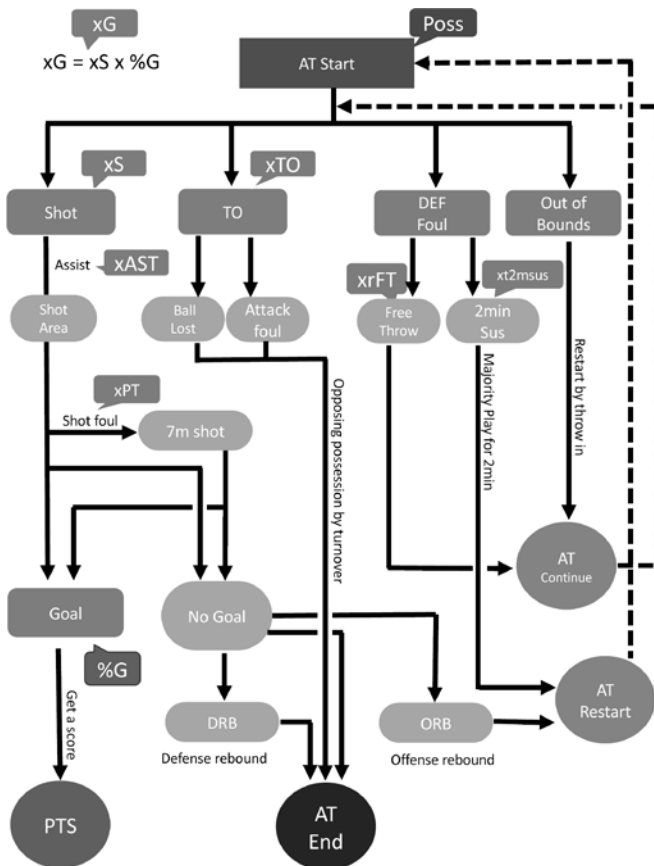


Figure 1 The flowchart of how to terminate of attack phase

The flowchart of how to terminate of attack was shown in figure 1. Based on figure 1, the we counted “Possession”, “Shot”, “Goal”, “Assist play”, “Turnover”, “Free throw”, “2 minutes suspension” during attack phase on each team. And, in this study, we made the attack and defense indexes based on terminate of attack or defense. Using these variables, we calculated the ratio of shot, goal, assist play, free throw, turn over and 2 minutes suspension against the possessions to make an index of expected shooting play (xS), expected goal (xG), expected received free throw (xrFT), expected turnover (xTO), expected taken 2minutes suspension (x2M) during attack phase. And shot efficiency (%G) and assist efficiency (%AST) also was calculated. Similarly, we made the defending index during opposing

possession. Expected opposing shooting play (OppxS), expected opposing goal (xL), expected turn over (OppxTO), expected free throw (xTFT), expected 2minutes suspension (Opp x2M) were calculated during attack phase. And opposing shot efficiency (%L) and opposing assist efficiency (Opp%AST) also was calculated.

### Data analysis

In order to confirm whether or not the created indexes are a useful index, a multiple regression analysis was performed using the xRFT, xTO, x7M, %G and %AST as an explanatory variable and goal score as an objective variable. Similarly, multiple regression analysis was performed for the defense index (opposing goal score, xTFT, OppxTO, Oppx7M, %L and Opp%AST).

We categorized using cluster analysis using selected variables to determine whether the indexes selected by multiple regression analysis affect team performance in each national league. We also classified the attack and defense index into 5 levels of “Excellent”, “Good”, “Average”, “Poor” and “Terrible” using 68-95-99.7 rules from data of average and standard deviation to evaluate the team performance.

## Results & Discussion

### Indexes of attack and defense phases

Table 1 was shown the average value of indexes of attack and defense for each team in JHL and table 2 was shown these in HBL. In JHL, there were significant differences in the values of xG and %G of attack indexes and xL and %L of defense indexes between the upper team and the bottom

Table 1 Attack and defense parameter of Japan Handball League in 2017-2018 and 2018-2019

Attack											
Team	n	Rank	Cluster	N of Attacks	N of Goals	xG	%G	xTO	xRFT	x7m	%AST
Osaki Electric	48	1	1	57.9±4.8	28.2±5.4	0.487±0.084*, #, \$	0.595±0.088*, #, \$	0.183±0.054	0.133±0.073	0.035±0.026	0.506±0.194
Toyoda Gosei	48	2	1	59.8±4.2	29±4.1	0.485±0.065*, #, \$	0.599±0.081*, #, \$	0.189±0.042	0.134±0.101	0.042±0.028	0.51±0.195
Toyota Auto Body	48	3	1	58.5±4.6	29.1±4.4	0.498±0.07*, #, \$	0.619±0.074*, #, \$	0.198±0.062	0.135±0.091	0.031±0.024	0.475±0.198
Daido Steel	48	4	2	56.9±4.2	26.6±3.5	0.468±0.059*, \$	0.567±0.063*, #, \$	0.176±0.05	0.142±0.074	0.046±0.03	0.509±0.179
Toyota Boshoku Kyushu	48	5	2	59.9±4.3	27.1±3.3	0.456±0.064*, #	0.562±0.075*, #	0.192±0.059	0.155±0.109	0.046±0.027	0.47±0.193
Wakunaga Pharmaceutical	48	6	4	57±4.8	23.8±3.6	0.418±0.061	0.528±0.075	0.206±0.051	0.164±0.105	0.033±0.025	0.491±0.165
Toyota Motor East Japan	48	7	3	55.8±4.5	24.2±3.7	0.434±0.057*	0.538±0.068	0.192±0.054	0.134±0.101	0.03±0.025	0.482±0.214
Hokuriku Electric Power	48	8	3	59.7±4.2	24.1±4.1	0.404±0.066	0.504±0.088	0.194±0.051	0.135±0.09	0.029±0.023	0.455±0.21
Ryukyu Corazon	48	9	4	58.7±4.7	22.1±3.6	0.378±0.067	0.474±0.077	0.206±0.068	0.157±0.094	0.036±0.026	0.435±0.224

Defense											
Team	n	Rank	Cluster	N of Defenses	Lost Goals	xL	%L	OppxTO	xTFT	Oppx7m	%OppAST
Osaki Electric	48	1	1	57.9±5.4	23.5±3.4	0.407±0.054*, #, \$	0.522±0.066*, #, \$	0.219±0.054	0.129±0.077	0.036±0.028	0.473±0.195
Toyoda Gosei	48	2	3	59.9±3.7	26±4.2	0.435±0.068*, #, \$	0.56±0.077*, #, \$	0.224±0.054	0.144±0.077	0.038±0.027	0.509±0.2
Toyota Auto Body	48	3	1	60±4.2	24.5±3.9	0.41±0.069*, #, & \$	0.509±0.079*, #, \$	0.198±0.045	0.124±0.085	0.046±0.029	0.512±0.202
Daido Steel	48	4	2	57.3±4.7	24.7±4.1	0.433±0.079*, #, \$	0.539±0.091*, #, \$	0.197±0.052	0.152±0.079	0.031±0.021	0.537±0.208
Toyota Boshoku Kyushu	48	5	3	59.8±4.3	28.9±4.9	0.483±0.071*, #	0.571±0.083	0.156±0.05	0.163±0.114	0.029±0.025	0.418±0.152
Wakunaga Pharmaceutical	48	6	2	57.6±3.9	25.4±4.9	0.441±0.08	0.531±0.095	0.168±0.047	0.138±0.084	0.041±0.024	0.527±0.215
Toyota Motor East Japan	48	7	3	55.6±5.2	25.9±4.3	0.466±0.071	0.572±0.086	0.183±0.058	0.179±0.118	0.035±0.026	0.421±0.208
Hokuriku Electric Power	48	8	4	58.7±3.6	29.6±4.7	0.505±0.078	0.619±0.084	0.184±0.054	0.12±0.076	0.037±0.027	0.445±0.172
Ryukyu Corazon	48	9	4	57.1±4.7	26.5±4.1	0.464±0.061	0.585±0.082	0.203±0.051	0.141±0.112	0.035±0.028	0.485±0.188

\* vs Ryukyu Corazon, p<0.01, # vs Hokuriku Electric Power, p<0.01, \$ vs Wakunaga Pharmaceutical, p<0.01

Table 2 Attack and defense parameter of Handball-Bundesliga in 2018-2019

Team	n	Rank	Cluster	N of Attacks	N of Goals	Attack					
						xG	%G	xTO	xRFT	x7m	%AST
SG Flensburg-Handewitt	22	1	1	50 ± 7	27.2 ± 4.9	0.547 ± 0.077*	0.639 ± 0.084	0.145 ± 0.04	0.184 ± 0.115	0.077 ± 0.037	0.472 ± 0.177
THW Kiel	14	2	1	51.8 ± 4	27.9 ± 4.4	0.54 ± 0.077*	0.631 ± 0.098	0.142 ± 0.032	0.232 ± 0.093	0.08 ± 0.039	0.452 ± 0.167
SC Magdeburg	17	3	1	53.2 ± 4.1	29.7 ± 4.3	0.557 ± 0.059*	0.661 ± 0.066*	0.157 ± 0.039	0.172 ± 0.101	0.094 ± 0.054	0.482 ± 0.213
Rhein-Neckar Löwen	14	4	1	50.6 ± 11.9	26.3 ± 6.6	0.53 ± 0.079	0.607 ± 0.094	0.124 ± 0.044	0.201 ± 0.161	0.056 ± 0.032	0.509 ± 0.165
MT Melsungen	13	5	2	52.8 ± 3.1	27.6 ± 4.3	0.525 ± 0.086	0.617 ± 0.086	0.151 ± 0.044	0.248 ± 0.164	0.07 ± 0.028	0.529 ± 0.227
Füchse Berlin	17	6	2	51.1 ± 5.2	26.9 ± 3.7	0.528 ± 0.063	0.644 ± 0.079	0.179 ± 0.04	0.288 ± 0.12	0.098 ± 0.033	0.61 ± 0.138
Bergischer HC	14	7	3	52.1 ± 3.5	26 ± 3.6	0.502 ± 0.08	0.588 ± 0.101	0.144 ± 0.041	0.211 ± 0.112	0.073 ± 0.044	0.539 ± 0.218
FRISCH AUF! Göttingen	15	8	3	51.6 ± 4	25.8 ± 4.8	0.5 ± 0.087	0.596 ± 0.105	0.16 ± 0.037	0.238 ± 0.105	0.083 ± 0.031	0.564 ± 0.208
HC Erlangen	21	9	2	50.2 ± 4.9	24.9 ± 2.7	0.5 ± 0.076	0.609 ± 0.087	0.177 ± 0.059	0.315 ± 0.129	0.075 ± 0.047	0.477 ± 0.14
HSG Wetzlar	15	10	2	49.3 ± 3.3	26.4 ± 3.5	0.537 ± 0.079	0.629 ± 0.077	0.147 ± 0.045	0.324 ± 0.131	0.086 ± 0.028	0.515 ± 0.137
SC DHfK Leipzig	15	11	2	50.5 ± 4	25.9 ± 4.1	0.515 ± 0.077	0.611 ± 0.077	0.158 ± 0.061	0.298 ± 0.141	0.057 ± 0.034	0.441 ± 0.111
TBV Lemgo Lippe	15	12	2	51.5 ± 3.8	25.1 ± 3.4	0.487 ± 0.048	0.589 ± 0.048	0.171 ± 0.061	0.337 ± 0.12	0.079 ± 0.052	0.525 ± 0.158
TSV Hannover-Burgdorf	22	13	1	50.7 ± 6.5	27.1 ± 4	0.537 ± 0.063*	0.628 ± 0.063	0.146 ± 0.048	0.21 ± 0.11	0.081 ± 0.037	0.531 ± 0.167
TSV GWD Minden	22	14	3	55.2 ± 4.6	27.5 ± 3.8	0.499 ± 0.058	0.596 ± 0.082	0.159 ± 0.049	0.204 ± 0.1	0.059 ± 0.033	0.47 ± 0.119
TVB 1898 Stuttgart	13	15	3	57.5 ± 3	27.8 ± 4.3	0.484 ± 0.072	0.586 ± 0.07	0.175 ± 0.063	0.185 ± 0.081	0.063 ± 0.038	0.355 ± 0.125
Die Eulen Ludwigshafen	19	16	4	49.8 ± 4.4	23 ± 3	0.464 ± 0.063	0.567 ± 0.068	0.182 ± 0.05	0.397 ± 0.17	0.063 ± 0.03	0.45 ± 0.195
VfL Gummersbach	13	17	3	52.2 ± 4.9	25.5 ± 3.6	0.488 ± 0.057	0.574 ± 0.065	0.149 ± 0.059	0.253 ± 0.132	0.052 ± 0.033	0.464 ± 0.196
SG BBM Bietigheim	9	18	4	48 ± 14.6	23 ± 8	0.451 ± 0.119	0.549 ± 0.139	0.184 ± 0.049	0.332 ± 0.151	0.066 ± 0.037	0.423 ± 0.173

Team	n	Rank	Cluster	N of Defenses	Lost Goal	Defense					
						xL	%L	OppxTO	xTFT	Oppx7m	%OppAST
SG Flensburg-Handewitt	22	1	1	51.4 ± 7	22.4 ± 4	0.442 ± 0.081	0.528 ± 0.077	0.166 ± 0.051	0.288 ± 0.174	0.074 ± 0.044	0.486 ± 0.155
THW Kiel	14	2	1	52.2 ± 4.2	24.8 ± 4.3	0.474 ± 0.07	0.585 ± 0.083	0.187 ± 0.064	0.303 ± 0.159	0.051 ± 0.032	0.443 ± 0.211
SC Magdeburg	17	3	1	54.7 ± 4.4	25.8 ± 3.7	0.473 ± 0.063	0.583 ± 0.074	0.188 ± 0.049	0.225 ± 0.114	0.071 ± 0.03	0.517 ± 0.203
Rhein-Neckar Löwen	14	4	1	48.7 ± 12.2	23.9 ± 6.9	0.471 ± 0.105	0.561 ± 0.118	0.165 ± 0.055	0.248 ± 0.188	0.062 ± 0.044	0.37 ± 0.168
MT Melsungen	13	5	2	53.8 ± 3.4	26.1 ± 3.4	0.487 ± 0.068	0.56 ± 0.074	0.132 ± 0.04	0.238 ± 0.133	0.082 ± 0.053	0.49 ± 0.16
Füchse Berlin	17	6	3	50.5 ± 4	27.3 ± 4.5	0.54 ± 0.072*	0.63 ± 0.077	0.143 ± 0.048	0.223 ± 0.109	0.076 ± 0.047	0.571 ± 0.154
Bergischer HC	14	7	4	51.1 ± 2.7	25.6 ± 2.8	0.503 ± 0.056	0.607 ± 0.086	0.168 ± 0.052	0.259 ± 0.085	0.062 ± 0.037	0.395 ± 0.123
FRISCH AUF! Göttingen	15	8	2	53.4 ± 3.5	25.9 ± 2.9	0.486 ± 0.054	0.57 ± 0.058	0.148 ± 0.046	0.17 ± 0.048	0.077 ± 0.035	0.604 ± 0.186
HC Erlangen	21	9	4	48.2 ± 3.5	25.5 ± 1.8	0.531 ± 0.04*	0.638 ± 0.055	0.166 ± 0.036	0.333 ± 0.161	0.081 ± 0.055	0.524 ± 0.142
HSG Wetzlar	15	10	4	50.5 ± 4.8	26.5 ± 4.6	0.523 ± 0.07	0.604 ± 0.081	0.133 ± 0.047	0.347 ± 0.14	0.067 ± 0.037	0.476 ± 0.195
SC DHfK Leipzig	15	11	1	49.7 ± 2.9	25.4 ± 2	0.512 ± 0.048	0.627 ± 0.067	0.182 ± 0.041	0.279 ± 0.148	0.073 ± 0.03	0.526 ± 0.138
TBV Lemgo Lippe	15	12	3	51.2 ± 3.7	27.4 ± 4.5	0.538 ± 0.098*	0.626 ± 0.109	0.14 ± 0.041	0.209 ± 0.099	0.068 ± 0.038	0.544 ± 0.138
TSV Hannover-Burgdorf	22	13	4	51.4 ± 6.7	27.8 ± 4.4	0.544 ± 0.069*	0.643 ± 0.069	0.154 ± 0.059	0.256 ± 0.121	0.082 ± 0.036	0.438 ± 0.138
TSV GWD Minden	22	14	4	54.9 ± 3.5	28.3 ± 4.3	0.517 ± 0.076	0.616 ± 0.078	0.163 ± 0.042	0.23 ± 0.113	0.072 ± 0.031	0.495 ± 0.135
TVB 1898 Stuttgart	13	15	3	57.4 ± 4.3	32.2 ± 3.1	0.562 ± 0.043*	0.666 ± 0.061	0.153 ± 0.051	0.164 ± 0.113	0.068 ± 0.029	0.476 ± 0.207
Die Eulen Ludwigshafen	19	16	3	49.3 ± 4	27.4 ± 3.4	0.557 ± 0.066*	0.652 ± 0.056	0.147 ± 0.039	0.224 ± 0.104	0.091 ± 0.034	0.552 ± 0.176
VfL Gummersbach	13	17	4	51.9 ± 5.3	27.6 ± 4.1	0.533 ± 0.069*	0.626 ± 0.084	0.147 ± 0.044	0.26 ± 0.148	0.083 ± 0.03	0.468 ± 0.231
SG BBM Bietigheim	9	18	4	47.8 ± 13.9	24.9 ± 6.6	0.538 ± 0.079*	0.638 ± 0.098	0.153 ± 0.059	0.296 ± 0.169	0.067 ± 0.041	0.497 ± 0.23

\* vs Die Eulen Ludwigshafen, p&lt;0.01, # vs SG Flensburg-Handewitt, p&lt;0.01

team in the final ranking. In HBL, the values of xG and %G was significant larger in upper team than in bottom team in the final ranking. In defense, SG the value of xL of Flensburg-Handewitt was smaller than that of bottom teams but there was not differences in the value of %L among teams.

In each league, required xG and xL for the final ranking to become the top 4 teams were analyzed using ROC analysis. In the JHL, required value of xG was greater than or equal to 0.466 and that of xL was less than or equal to 0.476. In HBL, required value of xG was greater than or equal to 0.545 and that of xL was less than or equal to 0.508.

These xG or xL indicate the ratio of the number of goal scores or opposing goal scores against number of attacking or defense possessions, and are very powerful indexes for evaluating team performance. However, xG and xL cannot clarify the details of their team performance because xG and xL include all attacking and defense information such as turnover and shot success rate. Thus, we have to search the more detailed indexes to evaluate the more detailed team performance.

**Search for useful attack and defense indexes for real time-match analysis**

As a result of correlation analysis between the attack index and the defensive index, very high correlation coefficient was observed between xG and %G and between xS and xTO. From the these results, these variables were considered to have multicollinearity. Thus, xG and xS were excluded from the variables for multiple regression analysis. In this study, we performed the multiple regression analysis to search the useful attack and defense indexes for real-time match analysis.

As a results of multiple regression analysis with attack indexes as an explanatory variables and goal score as an objective variable, the multiple regression coefficient were 0.814 and 0.617 in attack indexes in JHL and HBL, respectively. These results were statistically significant value (p<0.01). The standardized partial regression coefficient from each explanatory variable to the objective variable were as shown in Table 3. This result was shown that the influence on the goal score were in the order of %G, xTO, xRTF in attack phase. The results in defense phase were also similar. Therefore, we made the prediction formula as follows;

JHL

$$\text{Goal} = 44.889 \times (\%G) - 28.306 \times (xTO) - 5.941 \times (xRTF) + 7.462$$

HBL

$$\text{Goal} = 33.571 \times (\%G) - 24.467 \times (xTO) - 9.677 \times (xRTF) + 12.248$$

These formula also demonstrated that the impact of each index on the goal or opposing goal score. We found that %G has positive effect and xTO and xRTF has negative effect on the goal scores in attack phase. Thus, a high shooting efficiency led to high goal scores and the turnovers by offense ball lost, offense fouls, and/or intercepts led to be lower the goal scores. Interestingly, stopped the attack by a minor foul of an opponent defense player caused a low goal score. Thus, it is possible to perform simple and sufficient match analysis by counting the number of possessions, goals, turnovers, and free throws at each team's attack.

These three indexes for attack and defense are included in xG and xL, respectively (Figure 1). In other words, xG demonstrates the ability of the whole attack, %G demonstrates the goal ability, xTO demonstrates the ability to finish the attack with a shooting play, and xRTF demonstrates the ability to be able to continue the attacking behavior without being obstructed by the opposing defense. In defense, xL demonstrates the ability of the whole defense, %L demonstrates the to prevent the opposing goal ability, OppxTO demonstrates the ability to be finished the attack without

Table 3 Results of multiple regression analysis

	standardized partial regression coefficient	
	JHL	HBL
%G	0.845*	0.642*
xTO	-0.336*	-0.277*
xRFT	-0.134*	-0.299*
x7m	-0.024	-0.066
%AST	-0.051	-0.013

Table 4 Classification into 5 levels of indexes of attack and defense

	JHL			HBL		
	%G	xTO	xRTF	%G	xTO	xRTF
Great	0.732	0.082	0.000	0.772	0.059	0.000
Good	0.644	0.137	0.050	0.691	0.108	0.118
Average	0.555	0.193	0.143	0.610	0.158	0.251
Poor	0.467	0.248	0.236	0.530	0.207	0.384
Terrible	0.378	0.303	0.329	0.449	0.256	0.516

Table 5 The value of 3 indexes at match of TSV Hannover-Burgdorf vs F chse Berlin on 13th Sep in 2018

	Goals	Possession	xG	%G	xTO	xRTF
TSV Hannover-Burgdorf	28	49	0.571	0.683	0.163	0.061
F�chse Berlin	29	54	0.537	0.691	0.222	0.130

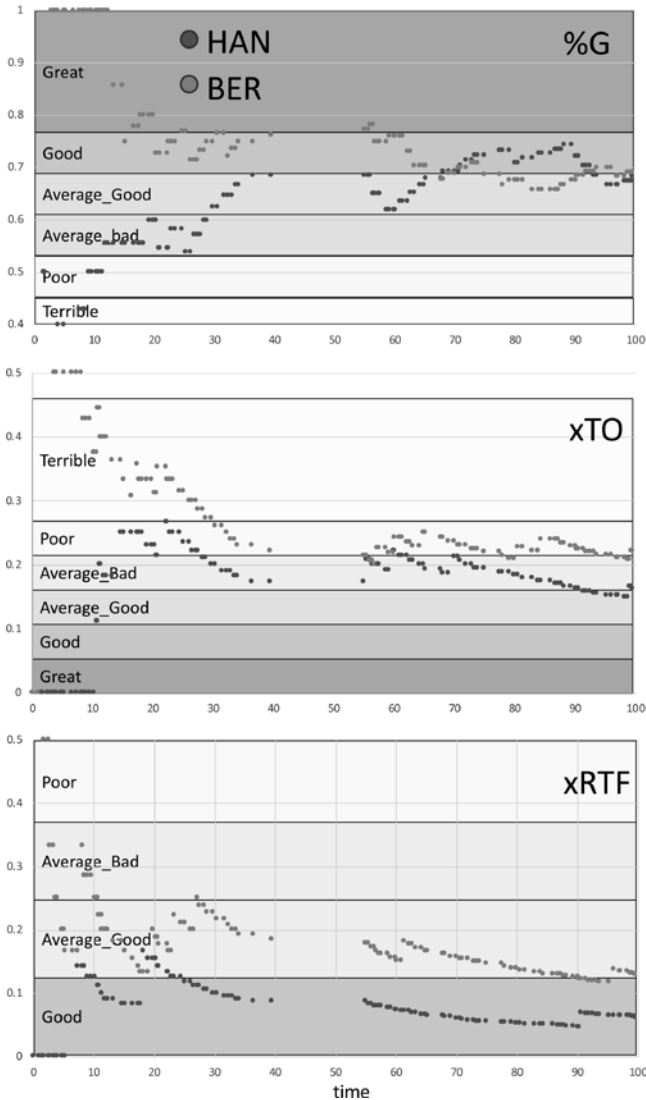


Figure 2 dynamic analysis of xTO, xRTF and %G

a shooting play against opposing offense, and xTTF demonstrates the ability to be able to stop the attacking behavior by the defender.

**Match analysis using variables selected in multiple regression analysis**

We performed cluster analysis in each league using useful indexes calculated by multiple regression analysis in attack and defense phase to clarify team performance. In JHL and HBL, each team could be classified into 4 clusters in both of attack and defense phases (Table 1, Table 2). From this result, the team's performance can be objectively evaluated not only by the match outcome but also by the performance of both attack and defense.

We also classified the useful indexes of attack and defense phase into 5 levels (Excellent, Good, Average, Poor, Terrible) using 68-95-99.7 rules from data of average and standard deviation to evaluate the team abilities. Table 4 was shown the results of classifying the value of %G, xTO and xRFT in attack phase and that of %L, OppxTO and xTFT in defense phase into 5 levels. We can perform not only the static match analysis but also the dynamic analysis (real-time match analysis) using this method. Table 5 was shown the results of the September 13th 2018 match between TSV Hannover-Burgdorf (HAN) and F chse Berlin (BER). The value of xRTF was "good" in HAN, "average-good" in BER, that of xTO was "average-poor" in HAN,

“poor” in BER, and that of %G was “average-good” in HAN and “good” in BER. From this result, this match can be analyzed as follows. In this match, HAN’s attack could be continued without being stopped by the opponent defense player, and the attack could terminate by a shooting play, compared to BER. However, the shot efficiency of HAN was lower than that of BER although shot efficiency was high level in both of team. Thus, the shot efficiency of BER was superior in this match. This superior shot efficiency of BER is considered to be a factor to win in this match. In addition, it is thought that an acquisition of the offense rebound greatly affected the outcome of this match because the number of possessions in BER was five times higher than HAN.

In addition, we can easily understand the status of the team performance on the own team and the opponent team during the match in real-time by using these indexes. For example, figure 2 was shown the results of dynamic analysis of each index data.

## Conclusion

In this study, we was to develop the useful statistical data indexes to evaluate the team performance of attack and defense during handball match, based on terminate of attack or defense phase. Therefore, We demonstrated that %G, xTO and xRTF on attack phase and %L, OppxTO and xTFT on defense phase are important and strong indexes in order to conduct a more detailed match analysis. %G has a positive effect and xTO and xRTF have a negative effect on the goal scores in attack phase. %L has a negative effect and OppxTO and xTFT has positive effect on the opposing goal scores.

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