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Original Article

Identifying performance indicators for success in the European men's handball championships.

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Abstract:
Handball is a dynamic team sport that requires a combination of individual and collective performance to achieve success. Understanding the key factors that influence team performance is essential for improving strategies and player efficiency. The study aimed to show which variables can predict performance levels in top men's handball. Data were collected from official box scores published by the European Handball Federation, which include offensive (court players' efficacy, assists and technical fouls) and defensive statistics (goalkeeper efficacy, steals, blocks, and two-minute suspensions). Data was compiled from five consecutive European handball championships, 2014-2022 (249 matches). A two-step cluster analysis was used to form three team groups, upper, middle and lower. The criterion variables per team were difference in total goals for and against, and points awarded per match played. MANOVA was used to compare all performance indicators between groups. A stepwise discriminate analysis (DA) was performed to identify performance indicator contribution to the team classification into the performance level groups. Statistical significance was set at $p<0.05$. Results showed significant differences in court player, goalkeeper efficacies, blocks and suspensions between the upper and lower groups. Differences were witnessed between all groups in assists, technical fouls and steals. Technical fouls and steals were found to be the key performance indicators for team discrimination. A set of performance indicators can predict the cluster grouping; thus, the game must be viewed from a multidimensional perspective.
Key Words: **Handball, European Championships, Key performance factors**

Introduction

Indoor handball has gained global recognition since the 1930s, with the inclusion of men's and women's World Championships and Olympic Games. Europe dominates the sport, hosting early European Championships in 1994. Handball is undergoing a dynamic process of development (Solovey et al., 2020) because of a multitude of factors such as professionalism, expansion of its athletic base, improved training methods as well as Talent Identification and Development that remains a multi-level field of research (Bjørndal et al., 2018; Lidor et al., 2005; Wrang et al., 2018).

Computer science development and notational analysis methods have promoted the understanding of one's own and opponent's strengths and weaknesses (Rudelsdorfer et al., 2014; Schrapf & Tilp, 2013) with the match. Time motion analysis of players' movements is used with computer vision systems to evaluate movement patterns and their acceleration profiles (Manchado et al., 2013). Rule changes and amendments have brought about not only game-played effects but also impacted the uncertainty of the outcome (Haugen & Guvag, 2018).
A key focus in match analysis research applied to team sports has been the performance indicators that differentiate winning and losing teams (e.g in basketball, see García et al., 2013, Lorenzo et al., 2010; in soccer, see Lago-Peñas et al., 2010; in volleyball, see Drikos et al., 2019, 2021).

Handball has seen a growing interest in analysing game strategies and performance factors. Recent studies have delved into various aspects of the game, from the pace of play to the impact of defensive tactics and goalkeeper. Meletakos and Bayios (2010) report an increase in the pace of the game as shown by the total number of goals scored per game from a sample of the European national league. More recently, Hatzimanouil et al. (2023), with a sample of final tournaments of the European Men's Handball Championships, focused on the analysis of fast game (fast breaks and fast throw–offs) and to what degree these variables could predict the final ranking of a team. Similarly, Ferrari et al. (2020), with a sample from European Champion League games focused on counterattack and fast attack as differentiating factors, among others, between winning and losing teams. Recent studies have investigated punishment within the game. Prieto et al. (2015), analysed the interactive effect of exclusions on both teams with a sample from the Spanish first league. On the same line of

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thought, Montoya (2016) examined numerical inferiority actions during the positional attack using data from the 2016 Olympics in Rio. The effect of permitted fouls on defensive performance was the objective of a study by Fasold and Redlich (2018) with a sample of 1052 attacking phases during games at the men's team elite level. Team performance was connected by Gomes et al. (2014) to time-out calling compared to match location, game period and point difference. The data on game outcomes of handball competitions refer largely to court player and goalkeeper efficacy variables. Goalkeeper performance and its relation to the match's final score have been thoroughly researched in many studies (Calin, 2015; Espina-Agulló et al., 2016; Hansen et al., 2017; Hatzimanouil, 2019; Hatzimanouil et al., 2017; Śliż & Dziadek, 2017).

The study of performance indicators and the search for differentiation in teams' tactical behaviour and teams' offensive and defensive patterns that characterize successful and unsuccessful teams is a field of interest for many researchers within handball research (Bilge, 2012; Hatzimanouil et al., 2023; Meletakos et al., 2020; Noutsos et al., 2018; Skarbalius et al., 2013). Previous studies have often classified teams based on their final tournament rankings. Since the nature of the tournaments restricts the all-teams-against-all scheme, these studies cannot confirm whether each team's final ranking reflects its performance. Weaker teams may progress to the later rounds of a tournament at the expense of stronger teams due to the tournament's structure and the paucity of matches (Vukičević et al., 2006). To address this limitation, this study categorised teams based on performance measures rather than final rankings, following the suggestion of Taylor et al. (2008).

This study hypothesises that by analysing various offensive and defensive performance indicators (shooting effectiveness, assists, blocks, etc.) of teams categorised into performance levels (upper, middle, lower) based on their actual performance rather than tournament rankings, differences between these groups will emerge. The research further aims to identify which of these metrics serve as the most reliable predictors of a team's overall performance level in the European Handball Championships.

Material & methods

This study focuses on the European male Handball Championships held every two years from 2014 until 2022. To carry out this study, data were collected from official box scores published by the European Handball Federation (EHF). The study includes total team statistics of all the teams during the 2014-2016-2018-2020-2022 European handball championships. Game-related statistics were collected by an experienced statistics company working for EHF. To provide evidence of the reliability of data 25 matches (10% of the total sample) were randomly selected from the total sample (249 matches) and team statistics were recorded by an independent handball expert. The weighted Cohen's kappa 0.95 showed very good values for inter-observer reliability. In this way, it was determined that the reliability of data was obtained from the official web page (http://history.eurohandball.com/).

Team performance was analysed based on the offensive (court players) and defensive (goalkeeper) effectiveness performance indicators according to the discrimination proposed by Meletakos et al. (2011). Some indicators reflect spatial areas in the court such as 6m., wing and 9m., while others reflect a situation of play such as 7m. (penalty shots), fast break, breakthrough and fast throw-off. The effectiveness of each offensive indicator was calculated by dividing the goals scored from the specific area or during the specific situation by the shots attempted and multiplied by 100. Additionally, the effectiveness of each defensive indicator was calculated by dividing the goalkeeper's saving by the shots attempted from the specific area or during the specific situation and multiplied by 100. Other performance indicators such as assists, technical faults, steals, blocks, and 2-minute suspensions were also considered. All these performance indicators were normalised according to the number of matches played by the teams per tournament. The full description of these spatial and situational offensive and defensive performance indicators is presented in Table 1.

Table 1. Listing and description of performance indicators

	Performance Indicators	Description
Offensive	Cp6m	Court players' effectiveness from the line player, from a zone outside the 450 angles from the left and right
	Cpwing	Court players' effectiveness from within an angle of 45^0 left and right without a defensive player in front.
	Cp9m	Court players' effectiveness from a backcourt player either (a) over or through the defence, and (b) after a breakthrough but with another defensive player in front.
	Cp7m	Court players' effectiveness from the seven-meter line (penalty) without a record of where the actual transgression was committed.
	Cpfb	Court players' effectiveness in fast breaks (until the defence is organized).
	Cbbrthr	Court players' effectiveness (a) by the backcourt players after breakthrough in the 9 m zone without a defensive player in front, (b) by the pivot after 1:1 situation, (c) by the left or right-wing after breaking through 1:1 situations).
	Fthroff	Number of Court players during fast throw-off
	Techfaults	Number of technical rule faults: offence fouls, double dribbling, enters of goal area, foot,

		steps
	Assists	Number of Assists per match
	Gk6m	Goalkeeper's saving effectiveness against the line player, from a zone outside the 450 angles from the left and right
	Gkwing	Goalkeeper's saving effectiveness against within an angle of 45^0 left and right without a defensive player in front.
	Gk9m	Goalkeeper's saving effectiveness against a backcourt player either (a) over or through the defence, and (b) after a breakthrough but with another defensive player in front
	Gk7m	Goalkeeper's saving effectiveness against the seven-meter line (penalty) without a record of where the actual transgression was committed.
Defensive	Gkfb	Goalkeeper's saving effectiveness against in fast breaks (until the defence is organized).
	Gkbrthr	Goalkeeper's saving effectiveness against a) by the backcourt players after breakthrough in the 9 m zone without a defensive player in front, (b) by the pivot after 1:1 situation, (c) by the left or right-wing after breaking through 1:1 situations).
	Gkfthroff	Goalkeeper's saving effectiveness against
	Steals	Number of Number of Steals per match
	Blocks	Number of Blocks per match
	2min	Number of 2min suspensions per match

A two-step cluster analysis (distance measure: log-likelihood, clustering criterion: Schwarz's Bayesian criterion) was used to group teams into competitive categories. The number of clusters was fixed at three (upper/middle/lower group). Due to the different number of played matches per team per tournament, the criterion variables were: the difference of total goals for and against and points awarded normalised per match played (win awarded 2 points, deuce awarded 1 point and defeat awarded 0 points). The first cluster (upper group) consisted of 25 teams (n=25), the second cluster (middle group) consisted of 45 teams (n=45) and the third cluster (lower group) consisted of 26 teams (n=26). The differentiation of the final ranking and the clustering for each tournament are presented in Figure 1.

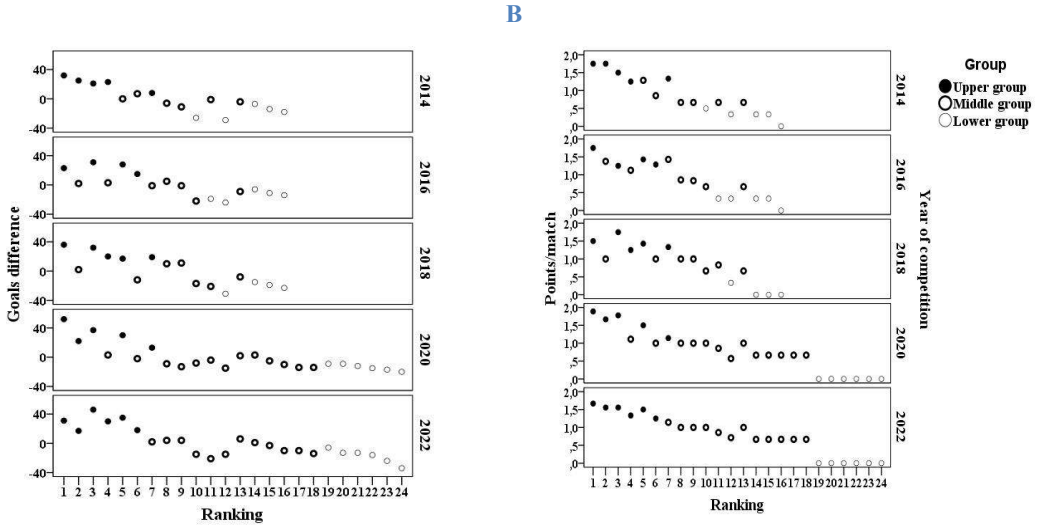

Figure 1. Goal differences (A) and points per match (B) of ranked teams (1^{st} to 24^{th}), per tournament, labelled by the cluster-analysis grouping.

Descriptive statistics were applied to determine means and standard deviations for the teams grouped as upper/middle/lower groups for each performance indicator. Multivariate analysis of variance (MANOVA) was used to simultaneously compare all performance indicators between the three groups of teams.

Moreover, a stepwise discriminate analysis (DA) was performed to identify the contribution of each performance indicator to the classification of the teams into the three groups of performance levels. The DAs were planned to determine three items: which variables were best predictors for the teams' success in the classification of performance level, the discriminate function that best separates the two group means and the accuracy of the equation that best discriminates teams' level. The comment of the obtained discriminant functions depended on the examination of the structure coefficients greater than |0.30|. It inferred that variables with higher absolute values have a greater contribution to discriminating between groups (Tabachnick & Fidell, 2007). In more details, loadings more than .71 are considered excellent, .63 very good, .55 good, .45 fair and .32 poor (Comrey & Lee, 1992). To decrease the bias entered in the classification, jack-knifed classification was used. The statistical analysis was performed using SPSS 23.0 software and significances were tested at $p<.05$.

Results

There was no multicollinearity between the independent variables as the simple correlations were all <|.4|), and the variables were not affected by moderate collinearity as tolerance values were from .646 for Cpwing to .845 for Gk7m, and variance inflation factors were small (from 1.199 for Cp9m to 1.547 for Cpwing). As Box's test of equality of covariance matrices was statistically significant (Box's M= 676.703, p= .006), indicating heterogeneity of the variance-covariance matrices across groups, the Pillai's trace multi-variate test was used (Tabachnick & Fidell, 2007). Additionally, the Bartlett Test of Sphericity (approx. Chi-square = 2610.094, df=189, p<.001) indicated that significant correlations were present among the dependent variables to proceed with the analysis.

Descriptive results derived from game-related statistics for the three groups' teams are presented in Table 2.

Table 2. Match descriptive statistics of offence and defence indicators, per performance grouping.

Indicators		Upper group		Middle group		Lower group		p
		Mean	SD	Mean	SD	Mean	SD	
Offensive	Cp6m (%)	71.64[b]	7.85	67.73	8.63	65.08	7.40	.018
	Cpwing (%)	64.32[b]	5.30	60.87	8.01	56.31	9.39	**.002**
	Cp9m (%)	47.12[b]	4.85	43.53	6.55	42.46	7.66	**.029**
	Cp7m (%)	76.48	7.74	77.18	11.70	75.46	13.14	.826
	Cpfb (%)	77.88	6.96	76.56	9.37	73.96	14.06	.386
	Cp brthr (%)	77.24	7.57	73.42	17.09	75.50	17.13	.593
	Fthroff	70.44	28.82	48.84	42.35	45.12	45.70	.051
	Techfaults (N)	8.82[a,b]	1.65	10.31	1.36	10.99	1.70	**<.001**
	Assists (N)	16.08[a,b]	2.64	14.05	3.44	12.28	3.65	**<.001**
Defensive	Gk6m (%)	25.80	7.57	25.38	6.18	24.38	9.59	.787
	Gkwing (%)	34.60[b]	6.90	31.42	7.74	28.54	7.11	**.016**
	Gk9m (%)	47.96	13.25	43.02	17.40	44.15	24.80	.571
	Gk7m (%)	22.40[b]	7.35	20.78	12.13	14.92	11.73	**.037**
	Gkfb (%)	18.40	6.95	15.00	8.02	15.00	7.68	.168
	Gkbrthr (%)	20.52	9.18	18.53	11.12	20.27	19.83	.800
	Gkfthroff (%)	17.64	24.82	6.71	14.50	9.85	22.37	.091
	Steals (N)	3.78[a,b]	.93	2.56	.88	2.16	.99	**<.001**
	Blocks (N)	2.49[b]	1.14	2.07	.93	1.76	1.01	**.041**
	2min (N)	3.45[b]	.84	4.11	.97	4.21	1.01	**.008**

Note: [a] significant difference to middle group, [b] significant difference to lower group, [a, b] significant difference to middle and lower group.

The main results of MANOVA showed that the linear combination of the twenty performance indicators differs significantly across the three levels of teams (Pillai's Trace=,813, F (38, 152) =2.737, p<.001, partial n^2=.406). A series of F tests were performed on each significant main effect of MANOVA. The variables Cp6m, Cpwing, Cp9m, Assists, Gkwing, Gk7m, Techfaults, Steals, Blocks and 2min were significant (see Table 2, last column). To determine specifically which groups differ significantly on each performance indicator, pairwise comparisons were assessed with Tukey test and the results are also presented in Table 2.

Two functions were established from the discriminant analysis presenting canonical correlations of .829 and .361. Function 1 explained 93.5% and function 2 explained 6.5% of the model's total variance (Figure 2).

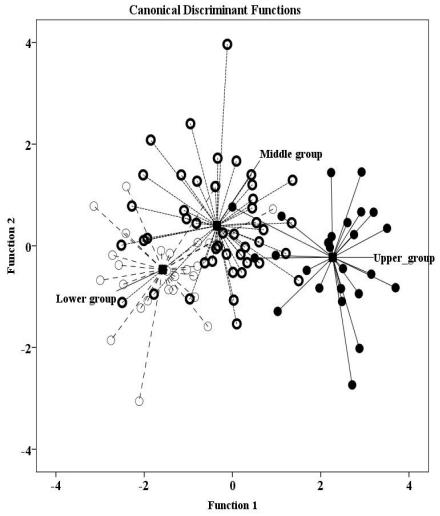

Figure 2. Combined map of canonical discriminant functions

The overall Wilk's lambda of Function1 was significant [Λ=.277, χ^2(38, N=96) =107.979, p<.001] indicating that the overall predictors differentiated between the three groups of teams. The canonical correlation (=.829) coefficient namely the measure of association between the discriminate function and the outcome variable is adequate. Consequently, the square canonical correlation (=.687) is the amount of variance accounted for by the discriminant function. Cross validations results showed that the discriminant function was correctly classified 20 out 25 teams for upper group, 29 out of 45 teams for the middle group and 10 out of 26 teams for the lower group (predictive accuracy 61.5%).

Structure coefficients (Table 3) with loadings >|.3| are meaningful and indicate the substantial contribution of the respective independent variables in the separation between the levels of the dependent variable (Pedhazur, 1997). So, the variables considered to be central in defining discriminant dimension performance level are steals (.464, fair) and tech faults (-.369, fair).

Table 3. Structure coefficients (SC) obtained from the discriminant analysis results for game-related statistics and tests of statistical significance.

Variables	Structure coefficients
Assists	.284
Cpwing	.246
Cp6m	.205
Cp9m	.191
Fthroff	.172
Cpfb	.088
Cpbrthr	.043
Cp7m	.014
Steals	.464
Techfaults	-.369
2min	-.220
Gkwing	.204
Blocks	.180
Gk7m	.152
Gkfb	.126
Gkfthroff	.124
Gk9m	.062
Gk6m	.043
Gkgrthr	.015

Their combination leads to the substantial explanation that the main difference between the three groups of performance level reflects mainly the status of just two variables, the ability of the court players to steal the ball from the opponents and to renew the ball possession and the ability to avoid technical fouls. The importance of the two variables' steals and technical faults in the accuracy of the discriminant function is presented in the scatter plot (Figure 3) with the real values of the two variables in the X and Y-axis and labels for the actual groups. The visual inspection of the scatter plot highlights benchmark values of 3 plus steals per game and 10 minus technical fouls per game for the upper group teams.

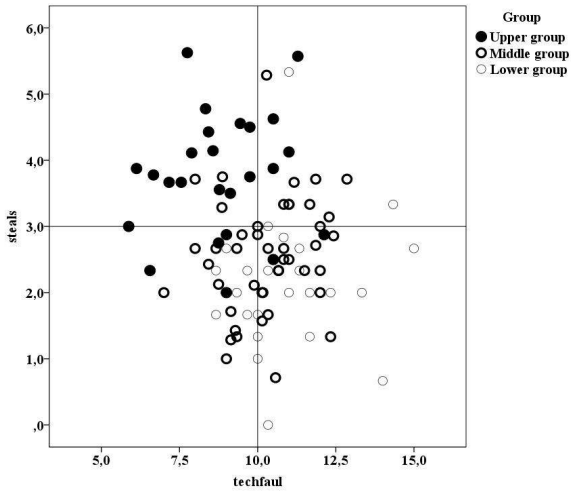

Figure 3. Scatter plot with values of the variables steals and technical faults for the actual group for all the teams.

Discussion

An important differentiation in this study is the admittance that tournament final rankings probably do not exclusively reflect the quality of the teams. The designation of sub-groups in the initial phase of the tournament as well as the crossmatches of teams in the knock-out games determine the final ranking of the teams. The rankings dependent on the difference of total goals, for and against, and points awarded, normalised per match played, were computed. Based on these criteria, a cluster analysis gave rise to three groups. The clusters consisted of three groups, the upper, the middle and the lower groups, each consisting of 25, 45 and 26 teams respectively.

According to our results, the differences in efficacy between the upper and lower groups were exhibited by shots from six meters, wing and nine meters. Our results correspond to those presented by Almeida et al., (2020) from a sample of men's world championships, with three-level groups (top elite, middle elite and low elite). Nine meters and wing court player efficacy showed statistically significant differences between the top elite and the other two, middle and low elite.

Line player six-meter shots are crucial for success, but the proximity to the goal and defensive pressure makes them challenging. Despite this, line players can significantly impact gameplay due to their high shooting efficiency and goal-percentage distribution (Meletakos et al., 2020).

The somatometric factor seems to be a significant parameter of success (Noutsos et al., 2019) but it was not one of the aims of the present study. However, the noteworthy somatometric characteristics in terms of body height, of the line player correlate with improved team performance (Meletakos et al., 2021). In this particular position, one has to credit additional elements that contribute to the game outcome such as supporting the actions of the backs (nine-meter players) with blocks and screens.

The study underscores the significance of assists, especially those leading to goals or penalties, as a crucial offensive metric. It finds notable differences in assists among the three performance groups, further emphasizing their importance. Effective assists demand exceptional individual technical and tactical skills and are often influenced by the defensive strategy employed, which can create scoring opportunities near the 6-meter line. Goalkeepers play a multifaceted role, not only safeguarding their net but also contributing offensively through swift counterattacks and initiating fast-paced gameplay. Teams at different performance levels exhibit significant differences in wing and penalty shot savings, highlighting the goalkeeper's crucial impact. For teams participating in the final of the European Men's handball, classified into the upper and middle groups, having capable goalkeepers is a distinguishable trait. Goalkeeper efficacy from 6m, for all groups, exhibits a stable characteristic of 25%.

The same pattern of goalkeeper efficacy can be seen from a 9m shoot, fast break and breakthrough. According to our results, significant differences arose for goalkeeper efficacy at 7m and wing, between the upper and lower group. One must keep in mind that goalkeeper performance is also dependent on defence. Tactical characteristics such as collaboration, the body height of the defender and the angle from which the wing player rises to shoot, all contribute to goalkeeper effectiveness and thus performance cannot be assessed on its own. The same differences witnessed between the three groups for court player and goalkeeper efficacies were also seen in blocks and 2 min. suspensions. Both variables are defence-related, the block prevents a possible successful shot. Similar results by Skarbalius et al. (2013) included the blocks as discriminating indicators between winning and losing teams from data of high-level national team matches. Blocked shots among other indicators such as height, 9m court player efficacy, number of international matches played, and wing court efficacy explained 85.3% of clustering. According to Almeida et al. (2020), from 2007 to 2019, a significant decrease from 3.46 to 2.06 per game, which agrees with the results in this study in blocks per game of 2.49, 2.07, and 1.76 for the upper, middle, and lower groups respectively.

The 2 min. suspension provide the opponent with a numerical superiority advantage and is a factor that our findings show is different between the upper and lower group. The defending team that has incurred a 2 min. suspension finds itself in a numerical imbalance. However, when the team manifests their attack, the goalkeeper is substituted for a court player to make up for their numeric inferiority (Montoya et al., 2016). There is a considerable negative effect on the number of goals scored by teams that have 2 min. exclusions (Prieto et al., 2015). Our study shows that fewer 2-minute suspensions lead to better placement, respectively shown by significant differences between upper and lower groups. Further elements such as the point during the match when the exclusion occurs, the goal difference, and of course the psychological factor of the penalised team (DeCaro et al., 2011).

The present study shows that two variable determinants, technical faults and steals contribute decisively to team classification in upper, middle, and lower groups. Technical fouls not only result in possession changes but also prevent an offensive play from culminating in a shot, providing the opposing team with an opportunity to counterattack, often leading to a quick and effective goal. Stealing the ball can facilitate an easy goal. In modern handball, defensive strategies are proactive, aiming to disrupt opponents' offensive plays and create scoring opportunities. The ability of a team to steal the ball is influenced by various defensive factors, including aggressive tactics, strategic formations, and positioning, but primarily by individual defensive skills such as tactical awareness, specific defensive attributes, and the ability to anticipate opponents' actions.

A key limitation of this study is that it relies on official box scores provided by the European Handball Federation (EHF). While the data underwent reliability checks, it might not capture all aspects of gameplay that contribute to team success. Additionally, the study focuses on analysing performance indicators like shooting efficacy, assists, blocks, and technical fouls. While these provide valuable insights, other factors such as player skill, coaching strategies, and team chemistry might also influence team performance. Another potential limitation is the variability in "rotation capacity" or "player availability" across teams. This factor could obscure the underlying reasons for performance differences, making it difficult to isolate the true causes. Teams with better rotation options might be more capable of maintaining high shooting accuracy or defensive intensity throughout the tournament, especially as player fatigue accumulates in later stages. The study only investigates European men's handball championships held every two years from 2014 to 2022. Results might not be generalisable to other handball competitions or women's handball.

Despite these limitations, the findings provide valuable insights into the factors contributing to team performance in European men's handball. The study highlights the importance of offensive efficiency (shots from 6m, wing, and 9m), defensive prowess (blocks, steals, minimising suspensions), and goalkeeper effectiveness (especially in wing and penalty shots) as key differentiators between successful and less successful teams. Furthermore, the study underscores the need for a comprehensive approach to team evaluation, considering not only performance indicators but also factors like tournament structure and individual player characteristics. Future research could explore the interplay of these factors to gain a deeper understanding of team success in handball.

Conclusions

The findings of this study emphasize the multidimensional nature of handball performance, where both offensive and defensive metrics, as well as individual player actions, play a critical role in determining team success. The study provides a comprehensive approach to evaluating team performance, offering valuable insights for coaches and analysts aiming to refine strategies and optimize player contributions in future competitions.

Future research could explore the interplay of various factors, including player characteristics, tactical approaches, and contextual variables, to develop a more holistic understanding of team performance in handball. Additionally, investigating the applicability of these findings to different levels of competition and women's handball could be a valuable avenue for further research.

Conflicts of interest: *No potential conflict of interest was reported by the author(s)*

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