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Performance-level indicators of male elite handball teams

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ABSTRACT

The aim of this study was to identify the most relevant variables to characterise the performance level of the teams through Men's World Championships (2007–2019). Forty-seven attributes from match-related statistics and characteristics of players were analysed in 168 participant teams. Descriptive discriminant analysis classified correctly 69.6% of the cases and selected the height of players, 9-m efficiency, international matches disputed, wing efficiency, blocked shots, 7-m goalkeeper efficiency and 2-min suspensions which were the most relevant indicators. Top-Elite was significantly different (one-way ANOVA) from Middle- and Low-Elite in all variables selected, except for 7-m goalkeeper efficiency. Linear regression shows that wing efficiency and blocked shots were the only variables with a tendency of changes through seven editions. The best teams have the tallest players and with more international matches disputed, were most efficient in 9-m and wing finalisations and block more shots in defence. These findings may guide scientists and sports trainers to select players, prescribe training procedures, analyse opponents and establish match strategies with special attention to these variables.

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Handball; performance determinants; match analysis; multivariate statistic

1. Introduction

Handball is an invasion team sport characterised by the dispute between two teams in a common court performing individual, group and team actions to score a goal and to prevent the opponent from scoring (Lamas, Barrera, Otranto, & Ugrinowitsch, 2014). For the offensive and defensive success, the players must coordinate tactical, technical and physical actions interacting with external (material and environmental conditions), individual (anthropometry, injury and nutrition) and team (cognition and social) factors (Wagner, Finkenzeller, Würth, & von Duvillard, 2014). Therefore, different tools are used to collect and analyse data that reveal the individual and team performance indicators in handball matches.

The match analysis in handball can be accomplished from static and/or dynamic perspectives. In the static analysis, the actions of players and team are registered through a notation system, usually in terms of descriptive frequencies of match events, without

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considering how it happened. In the dynamic analysis, the actions and critical events are registered in a chronological and sequential order establishing a direct relationship between the match events and the moment they occur (Prieto, Gómez, & Sampaio, 2015). The notation system by considering players' actions and critical events during competitive performance is a replicable and consistent method of recording sports performance (Hughes & Franks, 2015). In the most important international championships (Olympic, World and European), this method is used to match analysis, and the statistics obtained are published by International Handball Federation (IHF) and European Handball Federation on their official websites.

Several research studies have investigated the performance of high-level teams based on federation's data. Most of these studies used exclusively match-related statistics (actions of attack, defence, goalkeeper and punishments) to investigate which factors determine winners and losers teams (Foretić, Trninić, & Rogulj, 2010; Milanović, Vuleta, & Ohnjec, 2018; Ohnjec, Vuleta, Milanović, & Gruić, 2008; Saavedra, Dorgeirsson, Chang, Kristjánsdóttir, & García-Hermoso, 2018; Skarbalius, Pukenas, & Vidunaite, 2013; Vuleta, Sporiš, & Milanović, 2015), the differences between championship types (Bilge, 2012; Valentin, 2018) and between editions of the same championship (Meletakos, Vagenas, & Bayios, 2011) and performance in a single edition (Gutiérrez & Ruiz, 2013). In the reviewed literature, a single study included information of attributes of players (e.g. age, height, weight and international matches disputed) in addition to match-related statistics. That study, however, used a very restricted number of championships, editions and teams (Noutsos, Rousanoglou, Meletakos, Bayios, & Boudolos, 2018).

Some of the aforementioned research studies used multivariate statistics to conduct their investigations (Gutiérrez & Ruiz, 2013; Meletakos et al., 2011; Ohnjec et al., 2008; Saavedra et al., 2018; Skarbalius et al., 2013) since this technique allows to analyse the relationship between more than two variables and understand information, converting data into knowledge (Hair, Black, Babin, & Anderson, 2009). Under this perspective, other articles also studied the determinants of handball performance from notational data and multivariate analysis (Costa et al., 2017; Daza, Andrés, & Tarragó, 2017; Gruić, Vuleta, & Milanović, 2006; Hermassi et al., 2018; Massuça & Fragoso, 2013; Massuça, Fragoso, & Teles, 2014; Meletakos & Bayios, 2010; Pic, 2018; Vuleta et al., 2012). However, further studies should be conducted using match-related statistics in conjunction with players' characteristics, which potentially provides important information to understand the match and guide the training of high-level handball teams. The purpose of this study was to identify the most relevant variables to characterise the performance level of the teams in the Men's World Championships and analyse the behaviour of these variables through seven editions.

2. Method

2.1. Sample

This study was conducted using data from seven Men's World Championships, realised once every two years between 2007 and 2019 and published by the official website of the IHF. The reliability of data from IHF was verified by previous important studies which tested match-related statistics of 2005, 2007 and 2009 Men's World Championships

(Meletakos et al., 2011); 2017 Women's World Championship (Costa et al., 2017); and 2004, 2008, 2012 and 2016 Olympic Games (Saavedra et al., 2018). Very strong concordance between independent observers and IHF official notators was reported in all these research studies, with a Cohen's kappa coefficient greater than 0.80.

More precisely, the data set used in this study comprise "team roster", "cumulative statistics" and "ranking summary". Both team roster and cumulative statistics contain 168 samples, while ranking summary information contains 7 samples. Twenty-four national teams participated in each competition, divided into four groups that played the preliminary round, main round or president's cup and finals. To access this IHF website information (http://www.ihf.info/), the privacy policy and terms of use were read and accepted by researchers.

2.2. Data processing

The "cumulative statistics" files provided matches played, assists, technical faults, steals, blocked shots (BS), yellow card, 2-min suspensions and red/blue card. The total of goals scored, shots performed, shots defended by goalkeeper, shots received in the goal and efficiency (%) of the 6-m, wing, 9-m, 7-m, fast break (counter-attack) and breakthrough (advance through 9-m passing between defenders) finalisations were obtained from the same file. All these data were normalised according to matches played (6–10) by the teams.

The height, weight, age and average number of international matches of players were extracted from "team roster" files, and the team's final ranking in each competition accessed by "ranking summary". A performance-level variable was determined using the team's final ranking data to define the Top-Elite (1st–8th placed), Middle-Elite (9th–16th) and Low-Elite (17th–24th) groups. Top-Elite disputed final round (1st–4th) or placement matches (5th–8th), Middle-Elite were the worst ranked of main round (9th–12th) or the best of President's cup (13th–16th) and Low-Elite were the worst ranked of President's cup (17th–24th). Thus, a data set with 52 attributes and 168 records was structured using all variables described in Table 1, the competition year of World Championship and national team, selecting 47 predictive variables to analyses.

2.3. Statistical analysis

To identify the most relevant variables to characterise performance level (Top-Elite, Middle-
Elite and Low-Elite), a descriptive discriminant analysis was conducted using stepwise and Wilks' lambda methods with partial Fischer's values of 3.84 to enter and 2.71 to remove as criteria. Leave-one-out cross-validation method was used to validate the effectiveness of models into classifying unseen data correctly. Examination of the structure coefficients $|\geq 0.30|$ was used to interpret obtained discriminant function, which means that variables with higher absolute values were best placed to discriminate between groups (Pedhazur, 1997). One-way ANOVA was accomplished to compare the seven selected variables by stepwise method in the three clusters and Tukey-Honestly Significant Difference *post-hoc* test to identify pairwise differences. The angular coefficient obtained via linear regression and confidence interval (95%) were used to

Table 1. List of predictive variables of data set.

Variable Type	
Attack	Defence
6-meter goals scored	6-meter defended by goalkeeper
6-meter shots	6-meter received in the goal
6-meter efficiency	6-meter goalkeeper efficiency
Wing goals scored	Wing defended by goalkeeper
Wing shots	Wing received in the goal
Wing efficiency	Wing goalkeeper efficiency
9-meter goals scored	9-meter defended by goalkeeper
9-meter shots	9-meter received in the goal
9-meter efficiency	9-meter goalkeeper efficiency
7-meter goals scored	7-meter defended by goalkeeper
7-meter shots	7-meter received in the goal
7-meter efficiency	7-meter goalkeeper efficiency
Fast Break goals scored	Fast Break defended by goalkeeper
Fast Break shots	Fast Break received in the goal
Fast Break efficiency	Fast Break goalkeeper efficiency
Breakthrough goals scored	Breakthrough defended by goalkeeper
Breakthrough shots	Breakthrough received in the goal
Breakthrough efficiency	Breakthrough goalkeeper efficiency
Assists	Steals
Technical Faults	Blocked Shots
Punishment	Player's Characteristics
Yellow Card	Mean Height of all players (cm)
2 Minutes suspensions	Mean Weight of all players (kg)
Red/Blue Cards	Mean Age of all players (years)
	Mean International Matches of all players (count)

analyse the behaviour of these variables through seven editions (2007–2019) such as increase or decrease tendency (Ferrari, Vaz, Sousa, Couceiro, & Dias, 2018). The statistical significance was considered to the p-values <0.05, and the statistical analysis was performed in IBM SPSS Statistics for Windows (Armonk, NY: IBM Corp)

3. Results

Two functions were established from the discriminant analysis presenting canonical correlations of 0.74 and 0.41, respectively (Figure 1). Function 1 explained 85.3% of the model total variance and function 2 only 14.7% (Table 2). The model classified correctly 69.6% of the cases in the original group, being 76.8% in the Top-Elite, 60.7% Middle-Elite and 71.4% Low-Elite.

Among the selected variables by stepwise method, the mean height of all players (height), 9-m efficiency (9mE), mean international matches of all players (Imacth), wing efficiency (WingE) and BS had more weight for function 1, in order of their structure coefficients. In addition, the 7-m goalkeeper efficiency (7mE_gk) and 2-min suspensions (2 min) were the most relevant for function (Table 2).

Table 2 shows that mean values of height, 9mE, Imatch and WingE were statistically different between three clusters, being higher as the team level. Top-Elite teams presented more BS and less 2 min than the other two clusters, but there was no difference between Middle-Elite and Low-Elite. The 7mE_gk had significant difference only between Middle-Elite and Low-Elite teams.

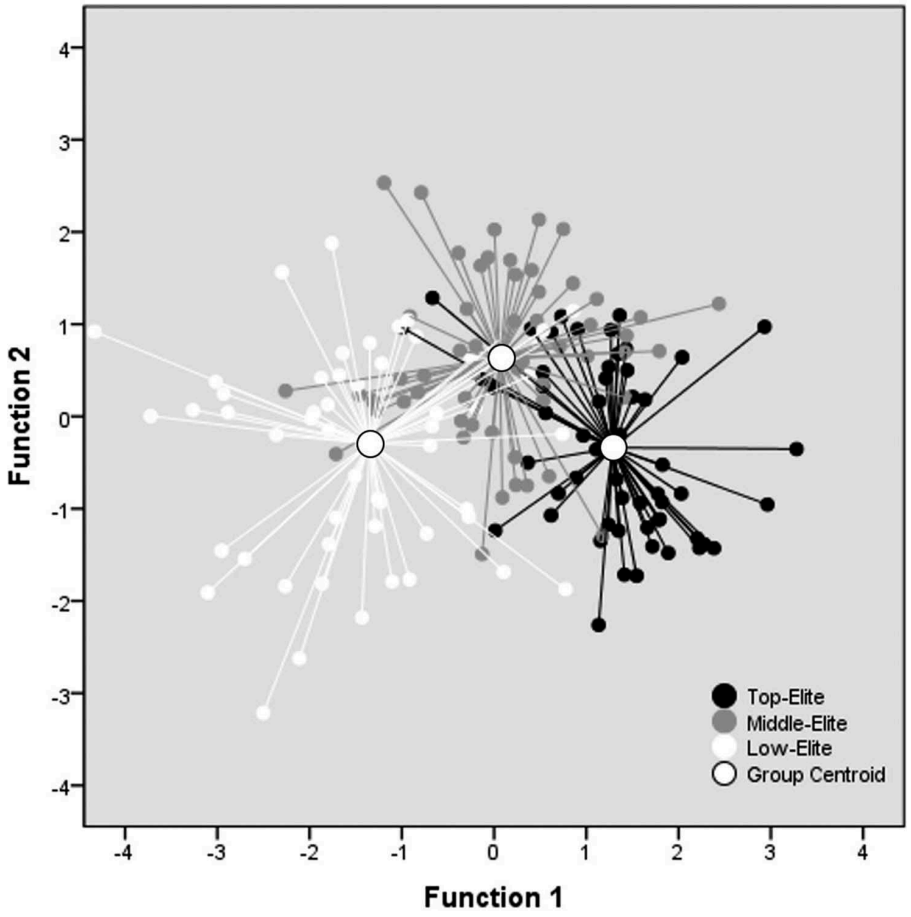

Figure 1. Territorial map of canonical discriminant functions.

Table 2. Structure coefficients of functions and comparisons between clusters.

Variables	Function 1 (85.3%)	Function 2 (14.7%)	Cluster 1 Top-Elite	Cluster 2 Middle-Elite	Cluster 3 Low-Elite
Height (cm)	0.66*	0.29	192.21 ± 2.22[a,b]	190.65 ± 2.53[b]	187.04 ± 4.00
9mE (%)	0.65*	0.05	43.93 ± 5.07[a,b]	39.98 ± 4.84[b]	34.87 ± 5.91
Imatch (count)	0.52*	−0.08	86.73 ± 30.59[a,b]	66.79 ± 26.32[b]	48.50 ± 26.83
WingE (%)	0.51*	−0.02	62.95 ± 8.42[a,b]	57.17 ± 8.16[b]	50.82 ± 10.15
BS (count)	0.45*	−0.32	3.43 ± 1.14[a,b]	2.45 ± 1.22	2.06 ± 1.07
7mE_gk (%)	0.13	0.55*	21.49 ± 7.51	24.69 ± 8.77[b]	18.74 ± 9.53
2 min (count)	−0.18	0.39*	3.78 ± 0.90[a,b]	4.35 ± 0.98	4.25 ± 0.93

Height = mean height of all players; 9mE = 9-m efficiency; Imatch = mean international matches of all players; WingE = wing efficiency; BS = blocked shots; 7mE_gk = 7-m goalkeeper efficiency; 2 min = 2-min suspensions. *Most relevant for function 1 or 2. [a]Significant difference to cluster 2; [b]significant difference to cluster 3.

Table 3 shows that the height was between 189.17 (2007) and 190.96 cm (2015) without increase tendency. The 9mE also had a stationary tendency and range of 37.40 (2015) at 41.06% (2017). Imacth had the highest value in 2007 (71.10) and lowest in 2015

Table 3. Means of most relevant variables across editions of Men's World Championships and parameters of linear regression.

									Confidence interval	
	2007	2009	2011	2013	2015	2017	2019	a	lb	ub
Height (cm)	189.17	190.04	190.10	189.63	190.96	189.86	190.00	0.056	−0.073	0.185
9mE (%)	39.33	39.85	38.53	40.02	37.40	41.06	40.96	0.111	−0.213	0.435
Imatch (count)	71.10	63.63	66.90	70.33	60.30	67.34	69.18	−0.112	−1.139	0.916
WingE (%)	51.56	54.74	55.55	54.00	60.70	60.75	61.56	0.843	0.424	1.263*
BS (count)	3.46	3.01	3.01	2.38	2.62	2.00	2.06	−0.118	−0.167	−0.070*
7mE_gk (%)	20.65	23.05	22.66	20.88	21.59	23.80	18.84	−0.090	−0.527	0.348
2 min (count)	4.08	4.00	4.03	4.00	5.07	3.65	4.08	0.006	−0.110	0.123

a = angular coefficient of linear regression; lb = lower bound; ub = upper bound; *Linear tendency to confidence interval for a ≠ 0 (alpha error 5%).

(60.30) without decrease tendency. WingE presented an increase tendency of 51.56 (2007) to 61.56% (2019), as did BS which decreased from 3.46 (2007) to 2.06 (2019).

4. Discussion

The discriminant analysis in the present study was consistent since it classified correctly 69.6% of the cases in Top-Elite, Middle-Elite or Low-Elite and a research that also discriminated three groups by team-level performance reported just 54.6% (Nikolaidis & Ingebrigtsen, 2013). A basketball similar research to the present study showed 59.0% of correctly classify to five groups divided by performance level of players (Zhang et al., 2018). Some handball studies showed correct classification of 83.0% (Saavedra et al., 2018) and 100% (Skarbalius et al., 2013) to winners and losers teams, 61.8–94.1% to successful and unsuccessful players (Massuça & Fragoso, 2013), 81.9% to regional and national players (Fernández-Romero, Suárez, & Cancela, 2016) and 87.2% to elite and non-elite players (Mohamed et al., 2009), but to discriminate only two groups.

The height, 9mE, Imatch, WingE and BS were the most relevant variables to discriminate national teams by performance level since these variables are more representative in function 1 of model that explained 85.3% of the variance. Expertise (age, international matches and international goals scored), the scoring and the anthropometric (height and weight) indexes determined the best ranked male teams of World Championship 2017 (Noutsos et al., 2018). To discriminate the level of players, the 30-m sprint time, performance on standing vertical jump, right handgrip, sit-ups, height, ability to vary their actions (Massuça & Fragoso, 2013), height, mean power in jump test (Nikolaidis & Ingebrigtsen, 2013), 10 × 5-m shuttle run, height (Mohamed et al., 2009) were the success indicators. These findings demonstrate the importance of including player's data, mainly anthropometrics and international experience, to investigate the performance indicators of handball in a multivariate perspective. The present study showed that players of Top-Elite, Middle-Elite and Low-Elite teams are differentiated by height (192.21, 190.65 and 187.04 cm, respectively) and Imatch disputed (86.73, 66.79 and 48.50 matches). It was evidenced that better-ranked elite teams have the tallest players and played more Imatch throughout their career (Bjørndal, Luteberget, & Holm, 2018).

Similarly, the match-related statistics presented higher values to the best-ranked teams, and some studies with multivariate analysis also revealed 9mE (Bilge, 2012; Foretić et al., 2010; Gruić et al., 2006; Skarbalius et al., 2013; Valentin, 2018; Vuleta

et al., 2015), WingE (Vuleta et al., 2015) and BS (Valentin, 2018; Vuleta et al., 2015) as important variables to determine the performance in elite handball. In fact, 9mE is a good predictor of success in male elite handball, and the present study found this range of values to Top-Elite (43.93%) and Middle-Elite (39.98%), with Low-Elite below (34.87%). The WingE values are higher than 9mE in Top-Elite, Middle-Elite and Elite (62.95%, 57.17% and 50.82%, respectively). Hence, the team that has target reach as in Top-Elite in World Championship must perform 18.26 shots scoring 8.02 goals per match from 9-m and 6.35 scoring 4.01 from the wing position, which is very close to the minimum requirement of efficiency in attack suggested for men's handball top competitions (Valentin, 2018). In defence, BS has an important role for team performance since Top-Elite blocked 3.43, Middle-Elite 2.45 and Low-Elite 2.06 shots per game.

Throughout the seven editions of World Championship analysed, the height, 9mE, Imatch, 7mE_gk and Imatch showed a stationary tendency from 2007 to 2019. On the other hand, WingE increased and BS decreased. In 2017, the 9mE had higher value and BS lower, which suggests the relationship between these variables since BS is invariably used in opposition to the 9mE. The WingE increase shows that elite national teams have been more effective on the extremity of court over the years.

The use of match statistics of international championships made available by federations for scientific studies was not recommended since the data are not peer reviewed (Wagner et al., 2014). However, several research initiatives have been published in scientific periodicals with both theoretical and practical insights and reliability of the data. Our study is focussed on high performances of elite handball competitions. Especially, the conducted multivariate analysis shows an excellent alternative to understand and interpret data of matches in handball.

5. Conclusion

In Men's World Championships since 2007, the Top-Elite teams (1st–8th) have the tallest players and with more international matches disputed, were most efficient in 9-m and wing finalisations and block more shots in defence. The efficiency in wing finalisations increased over the years, while BS decreased, evidencing a change of game pattern in elite handball teams. These findings may guide scientists and sports trainers to select players, prescribe training procedures, analyse opponents and establish match strategies with special attention to these variables.

Disclosure statement

No potential conflict of interest was reported by the authors.

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