


Performance differences and determinants of success in world men's handball championships

Panagiotis Meletakos¹ , Vasileios Manasis² , Konstantinos Noutsos¹ , Ioannis Bayios¹ 

¹National and Kapodistrian University of Athens, School of Physical Education and Sport Science, Team Sports Department, Athens, Greece. ²National and Kapodistrian University of Athens, School of Physical Education and Sport Science, Department of Theoretical Sciences, Athens, Greece.

Associate Editor : Gustavo R. Mota, Universidade Federal do Triângulo Mineiro, Uberaba, MG, Brazil. E-mail: grmotta@gmail.com.

Abstract - Aim It is to compare performance indicators among World Men's Handball Championships, 2017, 2019 and 2021. Taking into consideration that the last one took place under pandemic restrictions, and thus affecting all stages of preparation and competition, we also investigated indicators that mostly affected the teams' ranking. **Methods:** The sample consisted of sets of performance indicator variables specifically related to court player and goalkeeper efficacy, offense, defense, and punishment of all participant teams. We used the analysis of variance and the ordinary least square regression. **Results:** No significant differences in shots ($p = 0.165$, $\eta^2 = 0.046$) and goals per game ($p = 0.211$, $\eta^2 = 0.040$) were found in the last three successive world championships examined in our study. However, significant differences were found in court player efficacy at 6 m ($p = 0.000$, $\eta^2 = 0.226$) and breakthrough ($p = 0.047$, $\eta^2 = 0.077$) while for goalkeeper efficacy, differences were observed at 6 m ($p = 0.000$, $\eta^2 = 0.199$), penalty ($p = 0.049$, $\eta^2 = 0.099$) and fast break ($p = 0.005$, $\eta^2 = 0.132$). From the set of variables related to offense, defense and punishment, significant differences were observed only for assists per game ($p = 0.004$, $\eta^2 = 0.134$). **Conclusion:** The determinants of success of the top teams were the variables of court player efficacy and goalkeeper efficacy at 9 m followed by goalkeeper breakthrough efficacy, technical faults and 2-min suspensions per game.

Keywords: handball, performance indicators, Covid-19 pandemic.

Introduction

Handball is a dynamic and spectacular sport that is listed in the official Olympics program. Indoor men's handball was presented for the first time at the 1972 Olympic Games in Munich. This was followed by the introduction of women's handball in 1976 in Montreal¹. The first World Handball Championship took place in Germany in 1938, involving four teams from Europe made up of 7 players who competed in a round robin tournament for winner declaration. In the course of its historical development, there has been an increase in team participation. The next tournament took place in 1954, involving 6 teams. In 1958, marked the first significant increase to 16 teams which remained up to 1993. In 1995, there was a further increase to 24 teams. The 24 (4 groups of 6 teams) participating teams remained unchanged until 2019, while from 2021 in the World Championship in Egypt, the teams totaled 32 (8 groups of 4 teams)².

Another fundamental aspect of the game's development can be seen in the number of distinguished performance indices such as the increase of total number of

shots and consequently of goals scored per match³, the total number of attacks per game⁴, the significance in the improvement of player shot efficacy, in addition to the importance of somatometric characteristics⁵ that are predictors of top level performance. Body anthropometry, which is related to playing positions⁶, technical match characteristics as well as other factors such as the organizational structure of the competition seem to influence the final outcome⁷. These elements support the notion that a noticeable change in the sport is interrelated with a range of specific characteristics that influence team performance.

The notation system and the study of performance indicators employing data from the International Handball Federation has been the central topic of many studies concerned with men's and women's tournaments with the aim to highlight factors distinguishing successful and non-successful teams as well as the main differences that reflect technical and tactical changes. In a sample of Men's World Championships (2007-2019) 168 participating teams were analyzed using discriminant analysis. In 70% of the cases, the analysis correctly classified the contributing relevant indicators to be player height, 9-m efficiency, international

matches, wing efficiency, blocked shots, 7-m goalkeeper efficiency and 2-min suspensions⁸. In a sample of Women's World Championships but in the preliminary part of one competition (2003) consisting of four competition groups of six teams, the results showed that the final competition efficacy of the teams was dependent on a number of different factors⁹. Another study involving 101 matches played in the Men's World Championship in Croatia in 2009, an analysis of the winning and defeated teams showed that the winning teams were more efficient in all parameters in the attack actions where the pivot position played a crucial role¹⁰. In research encompassing data from Men's European Championships (2002-2010) concluded that 15 of the 28 examined variables were found to be key indicators. The winning teams scored more goals in total attacks and position attacks and goalkeepers exhibited high total efficacy¹¹. In four consecutive Olympic Games (2004, 2008, 2012, 2016), in women's handball matches, it was found that after discriminant analysis, five variables surfaced as the significant ones, exhibiting 83% correct classification. These were shots, goalkeeper-blocked shots, technical faults, steals, and goalkeeper-blocked fast-break shots¹². In another study involving an Olympic tournament (2012) using data from men's handball matches with fourteen attack mode variables and three defense mode variables, the results showed statistically significant differences between winning and defeated teams in the following variables: successful shot from 9 m, successful shots from the wing position, unsuccessful shots from the wing position, unsuccessful shots from 6 m, successful shots from 7 m, assists, lost ball-turnovers and blocked balls¹³. In the 2017 men's and women's World Handball Championship with a classification of teams in three groups of eight, the results showed that the variables that determined the men's and women's ranking were not the same¹⁴.

The 2021 World Men's Handball Championship that took place in Egypt from 13th to 31st January features a few important peculiarities. It took place during the ongoing Covid-19 pandemic, an unexpected situation that left no-one and nothing unaffected, including sports, culminating in the postponement of the Tokyo 2020 Olympic Games, for the first time in its history in times of peace. This pandemic affected not only ordinary citizens around the world relative to their physical activity but also amateur and professional athletes¹⁵. Handball is a sport that demands close physical contact and as such was seriously and directly affected due to preventive measures against Covid-19. The most noteworthy problems arose during the competition seasons 2019-2020 and 2020-2021. More specifically, the preparation period in both club and national team levels was inhibited while the athletic authorities were even forced to postpone or cancel championships in handball and in other professional leagues around the world while others were compelled to alter

scheduling due to lockdown measures and thus influencing team qualification in international events¹⁶.

The 2021 World Men's Championship had another unusual characteristic that of the absence of spectators, forced upon the organizers so as to contain the pandemic outbreak. To what degree the presence of spectators influences athletes' performance as well as other components such as referees has been the subject of many studies. Data from the National Basketball Association comprising seasons from 2007 through to 2016, expressed a causal link between size of the audience group and performance¹⁷. In a sample from football data across France, Germany, Italy, Spain, and the United Kingdom over the 2019/2020 season during Covid-19 lockdown, the absence of supporters drastically decreased the performance of the home team¹⁸. In a study involving athletes of Mixed Martial Arts, the performance of the fighters before and after Covid-19 was explored¹⁹. In a study involving empty stadiums in football, the behavior of the referee is influenced by the home-team fans²⁰. In a study of German professional soccer, the absence of audience for the first division decreased the home advantage during the Covid-19 pandemic while for the 2nd and 3rd division no change was observed²¹.

The aim of the present study is to compare selected performance indicators among three consecutive World Men's Handball Championships, 2017, 2019 and 2021 keeping in mind that 2021 took place under pandemic restrictions, affecting all stages of the competition and whether as a consequence this affected performance indicators. Furthermore, we investigated the performance indicators that mostly determine the final ranking position of the teams in the World Men's Championships under investigation.

Methods

Sample

The sample consisted of the total number of matches (288) played in three World Men's Handball Championships: 2017 (France) twenty-four participating teams (84 matches), 2019 (Germany/Denmark) twenty-four participating teams (96 matches), 2021 (Egypt) with initially 32 participating teams (108 matches), but due to Covid-19 cases in the Cape Verde team it was disqualified. Therefore, the results of the aforementioned team were not considered in our analysis.

Procedure and data

The variables that were studied were obtained from the official statistics of the International Handball Federation (IHF) (www.ihf.info) In every World Handball Championship, a group of specialized personnel use standard procedures to record every match. Thus, the present data are the officially recorded statistics. According to the

discrimination that was proposed by Meletakos et al.²², some variables reflect position, in other words a spatial area of the court, which are the 6 m, wing and 9 m, while others reflect a situation of play, the 7 m (penalty), fast break and breakthrough.

The variables that were analyzed were:

A- Overall set of variables:

1. Shots per game (*ShG*), stands for the number of shots attempted per game for the total six categories: six-meter, wing, nine-meter, penalty, fast break, and breakthrough.
2. Goals per game (*GoG*), stands for the number of goals per game for the total six categories: six-meter, wing, nine-meter, penalty, fast break, and breakthrough.

B- Court player efficacy set of variables:

1. Court player efficacy from six-meter (*CP6*), stands for shots, goals, from the line player - pivot, from a zone outside the 45° angle from the left and right. *CP6* is given by goals from six-meter/shots from six-meter $\times 100$.
2. Court player efficacy from wing (*CPw*), stands for shots, goals from within an angle of 45° left and right without a defensive player in front. *CPw* is given by goals from wing/shots from wing $\times 100$.
3. Court player efficacy from nine meters (*CP9*), stands for shots, goals, from a backcourt player either (a) over or through the defense, and (b) after a breakthrough but with another defensive player in front. *CP9* is given by goals from nine-meter/shots from nine-meter $\times 100$.
4. Court player efficacy from penalty (*CP7*), stands for shots, goals, from the seven-meter line (penalty). *CP7* is given from goals from penalty/shots from penalty $\times 100$.
5. Court player efficacy from fast break (*CPfb*), stands for shots, goals, in fast breaks (until defense is organized). *CPfb* is given by goals from fast break/shots from fast break $\times 100$.
6. Court player efficacy from breakthrough (*CPbth*), stands for shots, goals: (a) from the backcourt players after breakthrough in the nine-meter zone without a defensive player in front, (b) from the pivot after 1:1 situation, (c) from the left or right back after breaking through 1:1 situations. *CPbth* is given by goals from breakthrough /shots from breakthrough $\times 100$.

C- Goalkeeper efficacy set of variables:

1. Goalkeeper efficacy from six-meter (*GK6*), stands for shots, saves from the line player - pivot, from a zone outside the 45° angle from the left and right. *GK6* is given by saves from six-meter/shots from six-meter $\times 100$.
2. Goalkeeper efficacy from wing (*GKw*), stands for shots, saves from within an angle of 45° left and right without a defensive player in front. *GKw* is given by saves from wing/shots from wing $\times 100$.
3. Goalkeeper efficacy from nine-meter (*GK9*), stands for shots, saves from a backcourt player either (a) over or

through the defense, and (b) after a breakthrough but with another defensive player in front. *GK9* is given by saves from nine-meter/shots from nine-meter $\times 100$.

4. Goalkeeper efficacy from penalty (*GK7*), stands for shots, saves from the seven-meter line (penalty). *GK7* is given by saves from seven-meters/shots from seven-meters $\times 100$.
5. Goalkeeper efficacy from fast break (*GKfb*), stands for shots, saves in fast breaks (until defense is organized). *GKfb* is given by saves from fast break /shots from fast break $\times 100$.
6. Goalkeeper efficacy from breakthrough (*GKbth*), stands for shots, saves: (a) from the backcourt players after breakthrough in the 9 m zone without a defensive player in front, (b) of the pivot after 1:1 situation, (c) from the left or right back after breaking through 1:1 situations. *GKbth* is given by saves from breakthrough /shots from breakthrough $\times 100$.

D- Offensive set of variables:

1. Assists per game, (*AsG*). Last passes to successful goal shots or 7 m receiving.
2. Technical faults per game, (*TfG*). Losing ball possession.

E- Defensive set of variables:

1. Steals per game, (*StG*). Successful steals of the ball during dribbling or pass interceptions.
2. Blocks per game, (*BIG*). Defense block given to the defensive player blocking a shot of an attacker.

F- Punishment set of variables:

1. 2-min suspension per game (*S2G*).
2. Red cards per game (*RcG*).

G- Additional variables:

1. *D2019*, is a dummy variable for the 2019 Men's World Handball Championships.
2. *D2021*, is a dummy variable for the 2021 Men's World Handball Championships.
3. *Ranking*, stands for the final ranking position of a team.

Statistical analysis

All the variables have been subjected to descriptive statistical analysis prior to any comparison across championships. Based on the diagnostic test results prior to the analysis, we followed the classic one-way analysis of variance (ANOVA) that uses the F-test. More specifically, for the purposes of the study, we employed an ANOVA for all variables of interest with the championship (three levels) as the independent variable (factor). We employed the index of effect size (η^2) and for the post-hoc pairwise comparisons, we used the Bonferroni and Scheffe corrections.

The equality of variances has been tested via Levene's test while for testing the normality, we employed the Kolmogorov-Smirnov and Shapiro-Wilk tests on the residuals of the variables. The variables have also been tested for the presence of multicollinearity using the Pear-

son correlation statistic. Based on the results, no indication for the presence of serious collinearity was found since none of the examined pairs of variables was found to have a correlation higher than 0.70, which is a benchmark value according to Tabacknick and Fidell²³.

Lastly, the ordinary least square regression (OLS) has been used to identify the explanatory variables of the final ranking position. Starting with the initial OLS model, which includes all the variables of interest along with the dummies for the championships, we followed the backward selection to determine the factors that mostly affect the ranking position. Based on the final OLS model, an interaction with dummies is also tested for effect differences across championships.

Results

The ANOVA results for the indices shots per game (*ShG*) ($p = 0.165$, $\eta^2 = 0.046$) and goals per game (*GoG*) ($p = 0.211$, $\eta^2 = 0.040$) for the three competitions are shown in Table 1. The F-test for respective indices' shown does not show statistically significant differences in the three World Championships under investigation.

The ANOVA results for the indices included in the set of Court player efficacies for the three competitions are shown in Table 2. The F-test for the respective indices' show statistically significant differences in the court player efficacy from 6 m (*CP6*) ($p = 0.000$, $\eta^2 = 0.226$) and in particular a significant increase in efficacy from 2017, 2019 to 2021. As for court player efficacy from

Table 1 - Comparison of shots and goals per game between 2017, 2019 and 2021 Men's World Handball Championship.

Indices	2017 WCh	2019 WCh	2021 WCh	F _{2,76}	p-value	η^2
<i>ShG</i>	46.62	45.30	46.27	1.844	0.165	0.046
<i>GoG</i>	27.50	27.05	28.47	1.589	0.211	0.040

ShG: Shots per game, *GoG*: Goals per game, η^2 : Effect size.

Table 2 - Comparison of court player efficacies between 2017, 2019 and 2021 Men's World Handball Championships.

Court player efficacies (%)	2017 WCh	2019 WCh	2021 WCh	F _{2,76}	p-value	η^2
<i>CP6</i>	61.20 ^a	64.17 ^a	70.18 ^b	11.103	0.000	0.226
<i>CPw</i>	60.70	61.56	60.61	0.072	0.931	0.002
<i>CP9</i>	41.06	40.95	40.07	0.170	0.844	0.004
<i>CP7</i>	74.77	75.07	75.56	0.041	0.960	0.001
<i>CPfb</i>	77.98	79.88	75.59	1.782	0.175	0.045
<i>CPbth</i>	80.81 ^a	74.38 ^b	75.40 ^b	3.187	0.047	0.077

**Superscripts a & b: If different, this shows a significant difference.

CP6: Court player efficacy from six-meter, *CPw*: Court player efficacy from wing, *CP9*: Court player efficacy from nine meters, *CP7*: Court player efficacy from penalty, *CPfb*: Court player efficacy from fast break, *CPbth*: Court player efficacy from breakthrough, η^2 : Effect size.

breakthrough (*CPbth*) ($p = 0.047$, $\eta^2 = 0.077$), a significant drop was observed from 2017 to 2019, 2021.

The ANOVA results for the indices included in the set of Goalkeeper efficacies for the three competitions are shown in Table 3. The F-test for the respective indices show statistically significant decrease in goalkeeper efficacy from 6 m (*GK6*) ($p = 0.000$, $\eta^2 = 0.199$) from 2017, 2019 to 2021, a significant decrease in goalkeeper efficacy from penalty (*GK7*) ($p = 0.049$, $\eta^2 = 0.099$) from 2017 to 2019, 2021 and a significant increase from 2017, 2019 to 2021 in goalkeeper efficacy from fast break (*GKfb*) ($p = 0.005$, $\eta^2 = 0.132$).

The ANOVA results for the indices included in the set of variables related to offense, defense, and punishment for the three competitions are shown in Table 4. The F-test for the respective indices show statistically significant differences in the assists per game (*AsG*) ($p = 0.004$, $\eta^2 = 0.134$).

All the variables described in Section 2.2 have been included in the initial regression model with the *Ranking* as a dependent variable. Following a backward selection, we also tested the interaction effect of all remaining varia-

Table 3 - Comparison of goalkeeper efficacies between 2017, 2019 and 2021 Men's World Handball Championships

Goalkeeper efficacies (%)	2017 WCh	2019 WCh	2021 WCh	F _{2,76}	p-value	η^2
<i>GK6</i>	30.25 ^a	27.67 ^a	23.35 ^b	9.429	0.000	0.199
<i>GKw</i>	30.05	30.04	31.16	0.149	0.862	0.004
<i>GK9</i>	42.16	41.82	43.66	0.431	0.652	0.011
<i>GK7</i>	23.80 ^a	18.83 ^b	17.83 ^b	3.149	0.049	0.077
<i>GKfb</i>	13.65 ^a	13.31 ^a	19.04 ^b	5.760	0.005	0.132
<i>GKbth</i>	14.68	18.10	19.90	2.908	0.061	0.071

**Superscripts a & b: If different, this shows a significant difference.

GK6: Goalkeeper efficacy from six-meter, *GKw*: Goalkeeper efficacy from wing, *GK9*: Goalkeeper efficacy from nine meters, *GK7*: Goalkeeper efficacy from penalty, *GKfb*: Goalkeeper efficacy from fast break, *GKbth*: Goalkeeper efficacy from breakthrough, η^2 : Effect size.

Table 4 - Comparison of technical indices per game between 2017, 2019 and 2021 Men's World Handball Championships.

Technical indices per game	2017 WCh	2019 WCh	2021 WCh	F _{2,76}	p-value	η^2
<i>AsG</i>	14.30 ^a	13.02 ^{ab}	11.78 ^b	5.886	0.004	0.134
<i>TjG</i>	10.90	10.34	10.83	0.447	0.641	0.012
<i>StG</i>	3.17	3.51	3.60	1.035	0.360	0.027
<i>BIG</i>	1.99	2.06	1.91	0.165	0.849	0.004
<i>S2G</i>	3.64	4.07	4.09	2.554	0.084	0.063
<i>RcG</i>	0.08	0.13	0.18	1.855	0.163	0.047

**Superscripts a & b: If different, this shows a significant difference.

AsG: Assists per game, *TjG*: Technical faults per game, *StG*: Steals per game, *BIG*: Blocks per game, *S2G*: 2 min. suspensions per game, *RcG*: Red cards per game, η^2 : Effect size.

bles with the dummies *D2019* and *D2021* respectively. Based on the regression results presented in Table 5, the variables found to have a statistically significant effect on *Ranking* explain 66% of the variation. The negative sign coefficient for the three efficacy variables signifies a positive effect in *Ranking* or else a higher position in the final ranking. On the other hand, the positive sign coefficient for the technical faults per game (*TfG*) and 2-min suspension per game (*S2G*) variables results to a lower ranking position. The sign of the coefficients suggests that our model is well specified. The positive sign of the court player efficacy from 9 m (*CP9*) interaction with *D2021* denotes a lower effect for the 2021 World Championship (*WCh*). Figure 1 displays the required change in variables' value for a single higher ranking position in the final ranking at the world championship.

value for a single higher position in the final ranking at the world championship.

Discussion

The aim of the study was to compare selected performance indicators among three consecutive World Men's Handball Championships, 2017, 2019 and 2021 considering that 2021 took place under pandemic restrictions, affecting all stages of the competition and possibly the performance indicators. Furthermore, taking into consideration all Championships, we investigated the performance indicators that mostly determine the final ranking position of the teams.

The championships of 2017 and 2019 were organized under normal conditions while the 2021 championship was set up in grave circumstances, a global pandemic. This inevitably caused problems in the training process with an appreciable drop in the volume of training, intensity, frequency and duration²⁴. This was followed by the cessation of national championships, and reduced the number of preparation games and tournaments. During the 2021 World Championship, there was an additional oddity of "closed doors", the absence of an audience.

The variables shots per game (*ShG*) and goals per game (*GoG*), exhibited no significant differences in the three consecutive championships. These variables are closely connected with the pace of the game and our results are in accordance with Meletakos et al.²⁵, who used a sample from the national European championships, and Celes et al.²⁶, using data from the 2012 European Championship with results near to 46.5 shots per game. The absence of differences in these particular indices is of major importance because they can be correlated with time in attack in a 6 vs 6 situation, in fast break and fast throw actions, taking into consideration the multidimensional aspect of the mode of attack as a strategic team option but also as a variable related to game location and quality of the opponent²⁷.

It is accepted that efficacy, either of court players or goalkeepers, is evidently related to the success of the team. However, the play position and way the shot is to be taken is related to the individual technical and tactical ability within a strategic plan structured according to the advantages and weaknesses of the team and the opposing team, expressing a dynamic sense between attack and defense. The results of the set variables of court player efficacy from 6 m (*CP6*) exhibit significant differences in 2021 compared to the previous two competitions 2017, 2019. It seems that the pivot, (line player) continues to have a crucial role in the game. Using the line player (6 m) is a tactical choice and a strong way to play as seen by top teams²⁸ and is carving its niche in modern handball. The variable court player efficacy from breakthrough (*CPbth*) differs only in the 2017 WCh with respect to 2019 and

Table 5 - Regression results for 2017, 2019 and 2021 Men's World Handball Championships, dependent variable is *Ranking*.

Constant	17.064* (7.364)
<i>CP9</i>	-0.329** (0.105)
<i>CP9</i> * <i>D2021</i>	0.092** (0.027)
<i>GK9</i>	-0.194* (0.083)
<i>GKbth</i>	-0.247** (0.068)
<i>TfG</i>	1.433** (0.303)
<i>S2G</i>	1.531* (0.672)
R Adjusted-squared	0.669
No. observations	79

Numbers in parenthesis are standard errors.

*Significant at $\alpha = 5\%$.

**Significant at $\alpha = 1\%$.

CP9: Court player efficacy from nine meters, *D2021*, is a dummy variable for the 2021 Men's World Handball Championships, *GK9*: Goalkeeper efficacy from nine meters, *GKbth*: Goalkeeper efficacy from breakthrough, *TfG*: Technical faults per game, *S2G*: 2 min. suspensions per game.

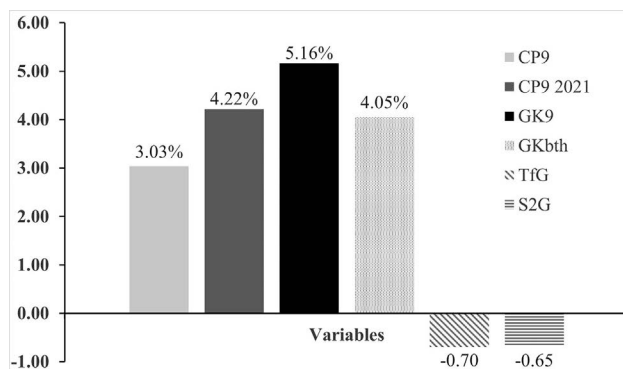


Figure 1 - Required change in variables' value for a single higher-ranking position in Men's World Handball Championships. *CP9*: Court player efficacy from nine meters, *CP9 2021*: Court player efficacy from nine meters for the 2021 WCh, *GK9*: Goalkeeper efficacy from nine meters, *GKbth*: Goalkeeper efficacy from breakthrough, *TfG*: Technical faults per game, *S2G*: 2 min. suspensions per game.

2020. This specific indicator relates to the defense employed by the team and the frequency of use if the opposing defense formation is broader or deeper and supports the importance of game strategy²⁹.

The set variables of goalkeeper efficacies that showed significant differences among the championships under investigation were goalkeeper efficacy from 6 m (*GK6*), goalkeeper efficacy from penalty (*GK7*), and goalkeeper efficacy from fast break (*GKfb*). The Goalkeeper position is decisive in the team's victory, but his performance depends on the position from which the shot is made, and the defense exhibited by the defending players whose behavior is correlated with the goalkeeper's efficacy and as such should always be taken into consideration³⁰. The significant difference of the 2021 World Championship of lower efficacy compared to 2019 and 2017 completely concurs with the result related to court player efficacy from 6 m (*CP6*).

The set variables concerning defense (blocks, steals), attack (assists, technical faults) and punishment (2-min suspension, red card) are related to team success³¹. The results showed a significant difference in the assists per game (*AsG*), here a gradual decrease can be seen from 2017 to 2021, bearing in mind its relation to defense formation and skills of the backcourt players. The absence of statistically significant differences in the remaining variables technical faults per game (*TfG*), steals per game (*StG*), blocks per game (*BlG*), 2-min suspension (*S2G*) and red card per game (*RcG*) seems to support the notion that the 2021 World Championship did not exhibit effects caused by external circumstances both at a technical or tactical level and referee decision making.

The regression model exhibits two statistically significant variables related to the 9 m, the court player efficacy from 9 m (*CP9*) and the goalkeeper efficacy from 9 m (*GK9*). From the effect of court player efficacy from 9 m (*CP9*), it is derived that an improvement of just 3% in the variable leads to one higher ranking position as long as the other variables remain constant. The effectiveness of the players at the 9 m is the ability to score from a long distance having one defensive player in front. Players possessing such skills are of decisive importance in the progression of the game and dictate the result of the success of the team, as the 9 m goals account for about 30% of the total goals scored by a team³². From the interaction of the court player efficacy from 9 m (*CP9*) with the dummy variable *D2021*, it can be implied that the effect of the court player efficacy from 9 m (*CP9*) in the ranking position decreased about 28% in 2021. The effect of the variable signifies that a 5% improvement in goalkeeper efficacy from 9 m (*GK9*) is required for one higher ranking position to be gained. In the same sense, goalkeeper efficacy when dealing with such shots, has a direct effect on the success of a team but as stated above, goalkeeper efficacy is related to defense formation and whether the

shots delivered are under defensive pressure³³. If we isolate those two variables, court player efficacy from 9 m (*CP9*) and goalkeeper efficacy from 9 m (*GK9*), a combined performance of 50% and 58% leads to the stage of final eight and final four teams respectively. Our results partially concur with those of Daza (2017)³⁴ who mentions that the performance of the goalkeepers are key performance indicators. With respect to the 2021 *WCh*, to secure a place among the top eight and the top four teams, the required combined performance of the court player efficacy from 9 m (*CP9*) and goalkeeper efficacy from 9 m (*GK9*) variables must increase to 60% and 70% respectively.

The goalkeeper efficacy from breakthrough (*GKbth*) is often among the lowest of Goalkeeper efficacies as can be seen by our results because this type of shot implies no defending player in front of the attacking player and therefore the probability of saving is small. However, in the end, if a goalkeeper manages to repel a number of such shots, this makes a difference for the team. To witness the effect of goalkeeper efficacy from breakthrough (*GKbth*), a 4% improvement leads to one higher ranking position. According to our results, there exists an obvious importance of the 9 m court players and goalkeeper and the corresponding indicators may well decide the outcome.

A technical fault means that the opposing team is given another attack opportunity, increasing the probability of scoring and thus it is found to have a significant negative³⁵ effect in the final ranking position. For the interpretation of the effect, a team that decreases the technical fault per game (*TfG*) by two, could advance almost three ranking positions, while a decrease of about one technical fault might lead to one higher ranking position, all other game parameters remaining constant. Whether a team is prone to technical faults is subject, among other reasons, to players' experience, technical skills, physical preparation, and the opposing team's defensive attitude.

The last variable entered in the regression model is the 2-min suspension per game (*S2G*). Based on our results, the number of suspensions approaches 4 per game, meaning that a team has player minority for 8 min. Consequently, the opposing team is given the opportunity to attack with greater effectiveness due to one player less in defense. The way a team takes advantage of this particular situation is a key success factor. Based on the coefficient effect, a team that succeeds in decreasing the number of 2-min suspension per game (*S2G*) by two, advances at least three ranking positions while a decrease in 2-min suspensions by at least 0,65 might lead to one higher ranking position. The absence of significant differences in 2-min suspension per game (*S2G*) and red card per game (*RcG*) in the three World Championships; it seems that the absence of audience in 2021 neither influenced referee decision nor player behavior.

For illustration purposes, a team that performs at least 50% in court player efficacy from 9 m (*CP9*) and the goalkeeper efficacy from 9 m (*GK9*) and commits nine technical faults per game (*TfG*) and three 2-min suspension (*S2G*), secures an entry to the stage of the final four teams. In this scenario, if the goalkeeper efficacy from breakthrough (*GKbth*) improves from the mean value (17.77%) to 26%, the team advances to the final or could even win the trophy by reaching a performance close to 30%.

Our results refer only to men's teams competing in the World Championships. They illustrate the trends in handball at top level, assisting coaches to devise more specialized training plans. At some point in the future, the study could be repeated to witness longitudinal differences.

Conclusions

Taking an overall view of all the set of variables, comparing 2017, 2019 and 2021, it seems that there are few differences in performance indicators between the three consecutive World championships. The 2021 World championship generally followed the same pattern as the other two championships.

Variables that influenced high level performance are those related to: court player efficacy from 9 m (*CP9*), goalkeeper efficacy from 9 m (*GK9*), goalkeeper efficacy from breakthrough (*GKbth*), technical faults per game (*TfG*) and 2-min suspension (*S2G*). The above results should be evaluated by coaches and technical directors for the special preparation of individual players and the team as a whole.

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Corresponding author

Panagiotis Meletakos. Eth. Antistaseos 41, Dafni 172 37, Athens, Greece.
E-mail: meletak@phed.uoa.gr.

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