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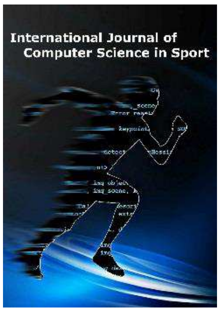

A comparison of tournament systems for the men's World Handball Championship

Peter O'Donoghue, Hafrún Kristjánsdóttir, Kristján Halldórsson, and Sveinn Þorgeirsson

Physical Activity, Physical Education, Health and Sport Research Centre, Reykjavik University, Menntavegi 1, 102, Reykjavik, Iceland

Abstract

The men's Handball World Championship commences with eight round robin groups of four teams before the "main round" of four groups of six teams. These groups of six each include the top three teams from pairs of initial groups. The tournament draw uses pots of eight which risks two teams in the top four appearing in the same group of the main round. A further issue is that teams finishing between third and sixth in the main round groups are awarded tournament places between ninth and 24th without any further matches. Therefore, the purpose of this investigation was to compare the current tournament system with alternatives using pots of four teams in the draw, and / or adding a knockout stage to place teams from ninth to 24th. These four tournament systems were simulated 100,000 times, using underlying regression models for the goals scored based on their World ranking points. Introducing pots of four increased the chance of reaching the quarter-finals for teams ranked one to four and nine to 12 by 1.3% and 1.6% respectively. It is recommended that the draw uses pots of four teams associated with pairs of initial groups that lead to common main draw groups.

KEYWORDS: PREDICTIVE MODELLING, SIMULATION, TOURNAMENT DESIGN, TEAM HANDBALL.

Introduction

The efficacy of a sports tournament can be viewed as the extent to which performers, whether teams or individuals, finish according to their ranking or ability. Tournament systems seek to give the best performers a higher chance of winning than weaker performers. At the same time, the tournaments need to have an element of uncertainty to maintain audience interest. Lasek and Gagolewski (2018) refer to this characteristic of competitions as the “beauty” of sports. The tournament systems used in sport have an impact on the efficacy of tournaments. Round robin tournaments, where each team plays each other team, have greater efficacy than knockout tournaments (McGarry and Schutz, 1997; Ryvkin, 2010). This is due to a general principle that tournaments with larger sets of matches lead to finishing positions that are more representative of quality of the performers (Lasek and Gagolewski, 2018; Csató, 2019). Some of Europe’s top soccer leagues operate double round robin formats where the teams play each other once at home and once away from home. For example, Spain’s La Liga, the English FA Premier League, the German Bundesliga, and Italy’s Serie A are double round robin tournaments. This is also the case for the top domestic handball league, the German Bundesliga. Round robin tournaments may involve performers competing against each other more than twice. Such tournament systems have been found to have greater efficacy than double round robin systems (Lasek and Gagolewski, 2018).

The disadvantage of round robin tournaments is the large number of games that each team has to play. Therefore, many international sports tournaments seek to have a higher efficacy than knockout tournaments while also requiring fewer games than round robin tournaments. Double elimination systems are similar to knockout systems but require performers to lose two matches before being eliminated. Double elimination systems have been found to have similar efficacy to single round robin systems while requiring fewer matches to be contested (McGarry, 2008).

The Olympic Games use hybrid tournament systems for team sports such as handball, basketball, soccer and field hockey. These hybrid systems consist of round robin groups followed by knockout stages and / or play-off matches. World Cup tournaments in soccer and rugby union also use hybrid tournament systems that combine initial round robin groups and a later knockout stage. Seeding improves the efficacy of tournaments where there are fewer matches than in round robin systems (Monks and Husch, 2009; Engist et al, 2021). However, Csató (2022a) has discussed situations where seeding can lead to teams benefitting from losing certain matches. Strategically losing certain matches can increase teams’ chances of achieving higher finishing positions within tournaments. This can happen when there have already been unexpected match results in the tournament.

The men’s Handball World Championships in 2021 and 2023 were contested by 32 teams who initially competed in eight round robin groups (A to H) of four teams. The increase from 24 teams potentially draws a wider audience for the tournament with associated commercial benefits. These groups are set up during the draw for the men’s Handball World Cup. The draw has four pots of eight teams, with the pots being broadly based on team quality. However, the highest ranked team from Africa was placed in Pot 1 in 2023, while the highest ranked teams from Asia and South America were placed in Pot 2. The remaining teams in Pot 1 were the top seven European teams, including Sweden who were a co-host and Denmark who were the holders having won the World Championship in 2021. The remaining teams in Pot 2 were the eighth to 13th ranked European teams, including Poland who were the other co-host. Pot 4 included two “wild card” qualifiers who were from Europe. One of these two teams was Slovenia who finished in 9th place in the 2021 tournament. This could result in unbalanced groups with respect to team quality. Each initial group has one team from each pot. This is a different process to that used in other sports where draws use seeding combined with processes to avoid more than one team from certain continents being in the same group. For example, in the FIFA World Cup it is possible to have two European teams in the same group because there are more European teams than the number of groups. However, teams from other confederations cannot be placed in the same groups from their own confederation. The Rugby World Cup also uses seeding, but has a disadvantage that the draw takes place over two years before the tournament. This means that teams' World rankings can change considerably before the tournament commences.

At the end of these initial round robin groups at the men's World Handball Championship, the top three teams in each group progress to the main round and the eight bottom teams compete in the President's Cup for places 25 to 32. The main round consists of four groups of six teams. Groups I, II, III and IV of the main round are made up of the qualifying teams from initial groups A and B, C and D, E and F, and G and H respectively. Consider main group I that consists of the three qualifying teams from initial group A and the three qualifying teams from initial group B. The results between these teams in the initial groups count within group I of the main round. This means that only nine further matches are needed in group I; the three teams from initial group A play against each of the three teams from initial group B. At the end of the main round, the top two teams from each group progress to the quarter-finals where a knockout tournament determines positions one to eight in the World Championship. The four winning quarter-finalists progress to the winners' semi-finals and the four losing quarter-finalists compete in the losers' semi-finals. The winners of the winners' semi-finals contest the final while the losers compete for third place. Similarly, the winners of the losers' semi-finals compete for fifth place while the losers compete for seventh place. The President's Cup is made up of two round robin groups of four teams. The two first placed teams progress to a play-off for 25th place, the two second placed teams enter the play-off for 27th place, two third placed teams enter the play-off for 29th place, and the two fourth place teams contest the play-off for 31st place. Places nine to 24 are determined from the performances of the teams finishing third to sixth in the four main round groups. This does not involve any further games for these teams. The records of the four third placed teams in these groups determine places nine to 12, while the records of the teams in fourth, fifth, and sixth places in these groups are used to determine places 13 to 16, 17 to 20, and 21 to 24 respectively.

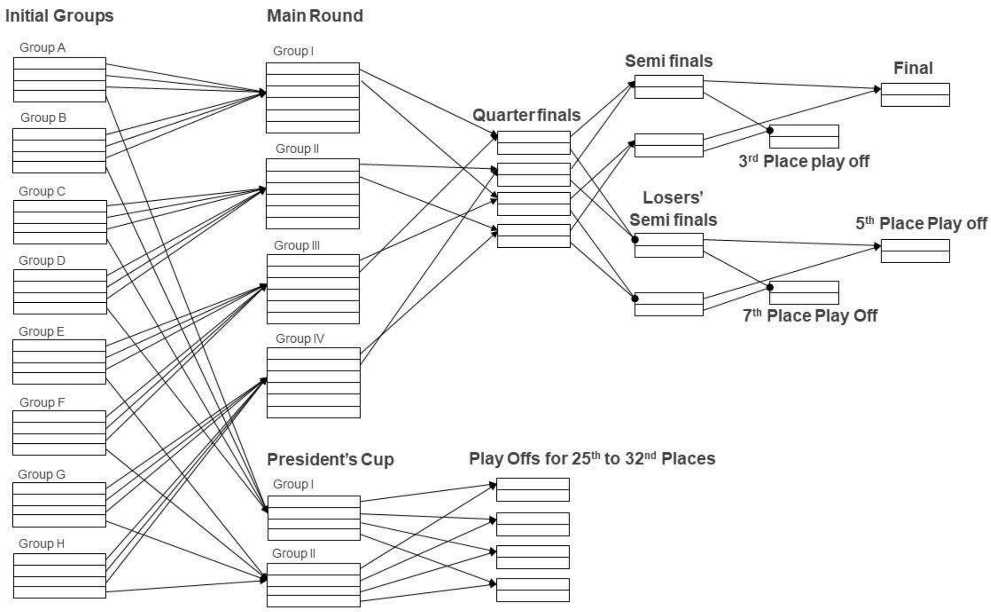

Figure 1. The tournament system currently used in the men's Handball World Championship.

Csató (2022b) discussed how carrying over two results from the preliminary group to the main round groups could lead to teams being disincentivised to perform to their best in the third preliminary group match. He described a real situation in the 1994 men's European Handball Championship where a team could benefit from a reduced margin of victory in a match, and in so doing eliminate a third team. There may be a strategic reason to do this if the third team is perceived as a threat the team's chances of progressing from the main round group. There may also be a benefit to the team's relative position within the three qualifying teams from the preliminary group when results are carried into the main round group. Some tournament systems used in international soccer (such as the men's and women's World Cups) involve the final matches within a group being played concurrently to help avoid such practices. A further possibility is that a team may have already qualified for the next stage after the penultimate group match; this would allow them to rest players in the final group match.

The only research to compare tournament systems for the men's Handball World Championship compared four versions of the tournament used between 1995 and 2019 (Csató, 2021). All four tournament systems involved 24 teams. Derivatives of Jackson's (1993) model of results were used rather than a model derived from historical handball data. Further tournament systems without seeding were investigated by Csató (2021), who also included knockout and round robin systems for comparison. The men's Handball World Championship now consists of 32 teams, warranting further research into the tournament system used. The pot sizes used in Castó's (2021) analysis were the same as the number of initial groups in the given tournament systems. Given that Handball World Championships pair the initial groups when forming the main round groups, it could be argued that the 2023 tournament is structured into four groups of eight because the teams within each group of eight commence as two groups of four, before the top three teams in each group form a group of six. Therefore, using pots of four teams in the draw for the tournament could be considered.

There are a number of criticisms that can be made of the tournament system for the men's Handball World Championship. As has been mentioned already, the draw for the initial round uses four pots of eight teams broadly based on their rankings. The issue here is that the initial groups are already paired with respect to main round groups that teams progress to. Therefore, two teams in the World's top four teams may end up in the same pair of groups and hence the same main round group. For example, France and Spain were drawn in initial groups A and B in the 2023 World Championship.

The second issue with the tournament system is the placings of the eight teams who contest the President's Cup. The first round robin group of the President's Cup is contested by the fourth placed teams in initial groups A to D while the second round robin group is contested by the fourth placed teams in initial groups E to H. There is a possibility that the four weakest teams in the tournament appear in the same group of the President's Cup. This would ensure that one of these teams finishes no lower than 26th place. By contrast, one of the four stronger teams in the second group of the President's Cup will finish no higher than 31st place.

The third issue with the tournament system is that the teams finishing in third to sixth places within the four main draw groups end up in places nine to 24 without playing any further matches. This could be fair if the ninth to 12th best teams in the tournament are in different groups of the main draw, with the same being the case for the 13th to 16th best teams, 17th to 20th best teams, and the 21st to 24th best teams. However, the pairing of initial groups combined with the use of four pots of eight teams during the draw, could lead to a situation where teams that ideally would be in separate main round groups could be in the same main round group. Even if the 13th to 24th best teams end up in appropriate main round groups, their performances in the main round will be influenced by the quality of the other teams in their groups. Consider the ninth to tenth best teams in the World. If the ninth best team in the World is in the same main round group as the best and fifth best teams while the tenth best team is in the same main draw group as the fourth and eighth best teams, the tenth best team could achieve a better points and goal difference record than the ninth best team by virtue of playing weaker opponents. The number of games in the tournament is a concern as the World Championship is played every second year, adding to the load on players who also compete for successful clubs. The purpose of the current investigation is to compare the tournament system used in the men's Handball World Championships with three alternative versions based on two modifications. The four systems being compared are:

- The current tournament system that uses four pots of eight teams in the draw.
- The first modification that uses eight pots of four teams to ensure the best four teams avoid each other in the main round, and that each subsequent set of four teams based on team strength avoid each other in the main round.
- The second modification that adds a knockout stage after the main round to determine the teams finishing in ninth to 24th places. This includes two knock out systems, one for places nine to 16 and one for places 17 to 24. Each of these have 12 matches set up the same way as the 12 matches currently used to determine first to eighth places. This modification adds three more matches for the middle 16 teams, meaning that each would play the nine matches in the tournament, which is the same number of matches as the teams making the quarter-finals.
- The third alternative tournament system uses both of the first and second modifications.

The four tournament systems are compared using simulations based on an underlying model of international handball results that uses team quality (ranking points) as an independent variable. The percentage of simulated tournaments where each team finished in each place from one to 32 is compared between the tournament systems.

Methods

Research design

This project is made up of a modelling stage and a simulation stage. The modelling stage uses match results from the 2021 and 2023 men's World Championships to determine models of World Championship match result in terms of relative quality of the teams. The relative quality of the teams within a match is the difference between their ranking points. Each match is always considered with respect to the higher ranked team in the match. The simulation stage is where the tournament is simulated with each match being simulated using the models developed from previous match data. There are four simulators; one for each tournament system being compared. Each simulator runs the tournament 100,000 times and accumulates the frequency with which each team finishes in each of the 32 positions. The simulation results are then used to compare the four tournament systems.

Modelling

Poisson distributions are used to represent the goals scored by each team within a match, rather than a single goal difference variable. This has an advantage over using only the goal difference, because it may be necessary to use goals scored in the event of points, head to head record and goal difference being identical between two teams in a group. This also has advantages over binomial distributions because Poisson distributions do not assume an upper limit for the goals scored within a match. Simulation of goals in soccer has also used Poisson distributions acknowledging the assumption that teams' goals are independent of the goals scored by their opponents (Dyte and Clarke, 2000). The objective of the modelling phase was to produce a pair of models using an independent variable representing team quality. The two models are for the goals scored by the higher ranked team and the lower ranked team within the match. Two pairs models were created using different measures of team quality. The most significant pair of models would be used in the simulation study. The first pair of models used the finishing places in the previous men's Handball World Championships while the second pair of models used ranking points determined by HB Statz (HB Statz, no date). For the first pair of models, the rankings for teams in the 2023 and 2021 World Championships were the finishing places in the 2021 and 2019 World Championships respectively. Some teams had not competed in the previous World Championships and so their matches were excluded from the first modelling exercise. There were 111 matches from the 2021 and 2023 World Championships that were used to create the first pair of models where both teams had competed within the previous World Championships. The independent variable was the difference in the teams' finishing positions in the previous World Championship. The use of separate models for the higher and lower ranked teams within matches was justified by the low correlation between the goals scored by higher and lower ranked teams ($r = -0.110$, $r^2 = 0.012$).

Curve estimation explored the relationship between goals scored by the higher and lower ranked teams within matches and the difference between their rankings. So, if the teams were ranked eighth and 13th in the World, the independent variable, ranking difference, would have a value of five. Logarithmic, linear, cubic, quadratic and inverse models were all significant for both the goals scored by the higher ranked teams ($p < 0.001$) and the lower ranked teams ($p < 0.001$). The logarithmic models for the higher ranked team's goals ($p = 0.000011$) and lower ranked teams' goals ($p = 0.000129$) were the most significant using this independent variable. The logarithmic models for goals scored by the higher and lower ranked teams are shown in equations 1 and 2 respectively.

$$Goals_{Higher} = 26.792 + 2.510 \ln(Rank_{Lower} - Rank_{Higher}) \quad (1)$$

$$Goals_{Lower} = 31.207 - 2.234 \ln(Rank_{Lower} - Rank_{Higher}) \quad (2)$$

The second pair of models used HB Statz ranking points of the two teams in a match that is based on an Elo system. The independent variable was the difference between the two teams' ranking points. As with the first pair of models, all matches were with respect to the higher ranked team. There were 180 matches from the 2021 and 2023 men's World Championships where both teams had ranking points values. The only matches excluded from this second modelling exercise involved a team that could not play some matches within the 2021 tournament. As with 111 matches used in the first pair of models, the goals scored by the higher and lower ranked teams within the 180 matches used here were unrelated ($r = 0.044$, $r^2 = 0.002$). Curve estimation revealed that linear models were the most significant when the independent variable was difference in ranking points. The p values for the models of the higher and lower ranked teams' goals were 0.0000050 and 0.0000002 respectively. Thus, the HB Statz ranking points are a more valid measure of team quality than finishing position in the previous World

Championship. Therefore, the pair of models based on ranking points was used in the current investigation. The two models are shown in equations (3) and (4).

$$Goals_{Higher} = 29.351 + 0.0089\ (Ranking\ Points_{Higher} - Ranking\ Points_{Lower}) \quad (3)$$

$$Goals_{Lower} = 28.055 - 0.0080\ (Ranking\ Points_{Higher} - Ranking\ Points_{Lower}) \quad (4)$$

There were two key considerations for using Poisson distributions within the tournament simulators for handball. Firstly, it was necessary to determine the number of goals a team could expect to score given their ranking points and the ranking points of their opponents. This would act as the mean for the Poisson distribution for the team's goals against the given opponent. The previously described pair of regression models were used to determine the mean for the Poisson distributions of the higher and lower ranked teams' goals.

Secondly, it was necessary to set a lower limit for the number of goals scored by a handball team in a match. Poisson distributions include cardinal numbers from zero upwards. Realistically, teams do not score zero goals in World Championship handball matches. The lowest number of goals scored by any team in any match in the men's World Championships from 2015 to 2023 is 12. Therefore, it was necessary to determine a fixed lower limit for goals scored with additional goals scored following a Poisson distribution. A Poisson distribution would be applied to determine the number of additional goals above this minimum. The minimum number of goals scored in the 180 matches used to create the pair of models was 18 for the higher ranked team in a match and 12 for the lower ranked team. We tested to see which combination of minimum goal values and Poisson distributions would produce results closest to those observed in the data used to create the models. The 180 matches used to create the pair of models contained 146 wins (81.1%), 14 draws (7.8%), and 20 losses (11.1%) for the higher ranked teams within the matches. An R script was written to apply each minimum goals value for the higher ranked team from zero to 18 and each minimum goals value for the lower ranked team from zero to 12. For each combination, each of the 180 matches used to create the model was simulated 100 times using the minimum goals values and Poisson distributions with means being the predicted goals values with the minimum goals values subtracted. For each combination of minimum values, the percentage of the 18,000 simulated matches that were wins, draws and losses for the higher ranked team were compared to the percentages observed in the 180 actual matches played. The test statistic of the chi square goodness of fit test was used to represent how well the distribution of simulated match outcomes represented the actual distribution. The best combination was when a minimum value of 18 was used for the higher ranked team's goals and a minimum value of 12 was used for the lower ranked team's goals. This combination had the minimum chi square test statistic ($\chi^2_2 = 3.1$) and a simulated 80.3% wins, 4.1% draws, and 15.3% losses for the higher rankled teams within matches.

Model validation

The model was validated using data from the 2015, 2017 and 2019 men's World Championships (268 matches). Firstly, there was no correlation between the higher and lower ranked teams' goals within matches ($r = 0.078$, $r^2 = 0.006$). This agreed with the analysis of the 2021-23 data. Secondly, curve fitting revealed that the most significant models for higher and lower ranked teams goals were linear when difference between the teams' HB Statz ranking points was used as an independent variable. This concurred with the curve fitting applied to the 2021-23 data. Thirdly, the linear models were very similar to the models shown in equations (3) and (4).

Equations (5) and (6) show the models for higher and lower ranked teams' goals respectively that were produced from the 2015 to 2019 matches.

$$\text{Goals}_{\text{Higher}} = 27.084 + 0.0099\ (\text{Ranking Points}_{\text{Higher}} - \text{Ranking Points}_{\text{Lower}}) \quad (5)$$

$$\text{Goals}_{\text{Lower}} = 27.285 - 0.0088\ (\text{Ranking Points}_{\text{Higher}} - \text{Ranking Points}_{\text{Lower}}) \quad (6)$$

The fourth step of the validation process was to test if similar offsets for the Poisson distributions would be produced from the 2015 to 2019 data. The R script used determine the offsets to use with the Poisson distributions was modified to apply the models in equations (5) and (6). These models were applied to the HB Statz ranking points for the teams contesting 180 matches of the 2021 and 2023 men's World Championships. The best fit between the simulated wins, draws and losses for the higher ranked team was achieved with offsets of 17 and 12 for the higher and lower ranked teams' goals respectively (75.9% wins, 4.9% draws, 19.2% losses, $\chi^2_2 = 7.2$). This almost matched the offsets of 18 and 12 determined to be used in the current investigation. Indeed, offsets of 18 and 12 gave the 3rd best fit of the 247 combinations of offsets that were tested in the validation study.

Simulation

The simulators assumed that the World's top 32 teams would compete in the tournament and that a team's ranking points would be the mean ranking points for teams with the same ranking position in 2019, 2021 and 2023. For each match being simulated, equations (3) and (4) were used to determine the predicted goals for the higher and lower ranked teams. The minimum values of 18 and 12 were subtracted from these to determine the means to use within the Poisson distributions for the two team's goals. The simulated goals for each team in a match were random numbers from these Poisson distributions with the minimum goals values added back on.

Each version of the tournament was simulated 100,000 times, drawing the teams into initial groups, playing each match within each stage, and applying the tournament rules to determine teams progressing to the next stages as well as final placements within the tournaments (IHF, 2000).

When the simulator completed a group, the teams were ordered on points, then head-to-head points, head-to-head goal difference, head-to-head goals scored, then goal difference. Where the simulation resulted in a tie for a knockout match, a 5-minute period of extra time was simulated. If the teams were still tied, a second 5-minute period of extra time was simulated. The means used within Poisson distributions for extra time periods, divided the predicted goals for the 60-minute match by 12 without using offsets. If the teams were still tied after two periods of extra time, then penalties were simulated by selecting a winner at random with each team having a 0.5 probability of winning on penalties.

A 32 x 32 (team by finishing position) matrix accumulated the teams' finishing position statistics from the 100,000 simulated tournaments. The frequency of simulated tournaments where teams finished in each position were then compared between the different tournament systems.

The proportion of times each team finished in the same position as their World ranking was determined for each tournament system. The average of these 32 proportions was determined for each tournament system, providing a further metric on which to compare the four tournament systems.here.

Results

Figure 2 shows that there is very little difference to teams' chances of winning the tournament when comparing the four tournament systems. However, Figure 3 does show that using eight pots of four teams during the draw increases the chances of the top four teams reaching the quarter finals and that this is at the expense of the chances of the teams ranked five to eight. The lines for the two tournament systems that use an extra knockout stage to determine positions nine to 24 are very similar to the corresponding lines where the additional knockout stage is not applied. The currently used tournament system of four pots of eight teams had an average proportion of 0.127 tournaments where teams would finish in the same position as their World ranking. This was increased to 0.135 when eight pots of four teams were used and 0.132 when knockout stages were added to determine ninth to 24th places. When both eight pots of four teams were used and knockout stages were used to determine ninth to 24th places, the average proportion for teams finishing in their expected places was 0.136. Table 1 shows that introducing eight pots of four increases the top four teams' chances of winning the tournament. Table 1 also shows that introducing pots of four teams increases the chances of teams ranked one to four, nine to 12 and 17 to 20 making the quarter finals at expense of teams ranked five to eight, 13 to 16, and 21 to 24. Table 2 shows that introducing eight pots of four teams increases the chances of higher ranked teams finishing in the top four positions, as well as slightly increasing the quality of the teams contesting the final. Applying both eight pots of four teams and introducing knockout stages to determine places nine to 24 does make a further slight increase in the quality of the teams contesting the final and the percentage of tournaments won by the highest ranked team. However, this is at the expense of organising 24 additional knockout matches, meaning each team reaching the main draw but failing to reach the quarter-finals would play nine games instead of seven matches as it is now, while those in the President's Cup would continue to play 7 matches.

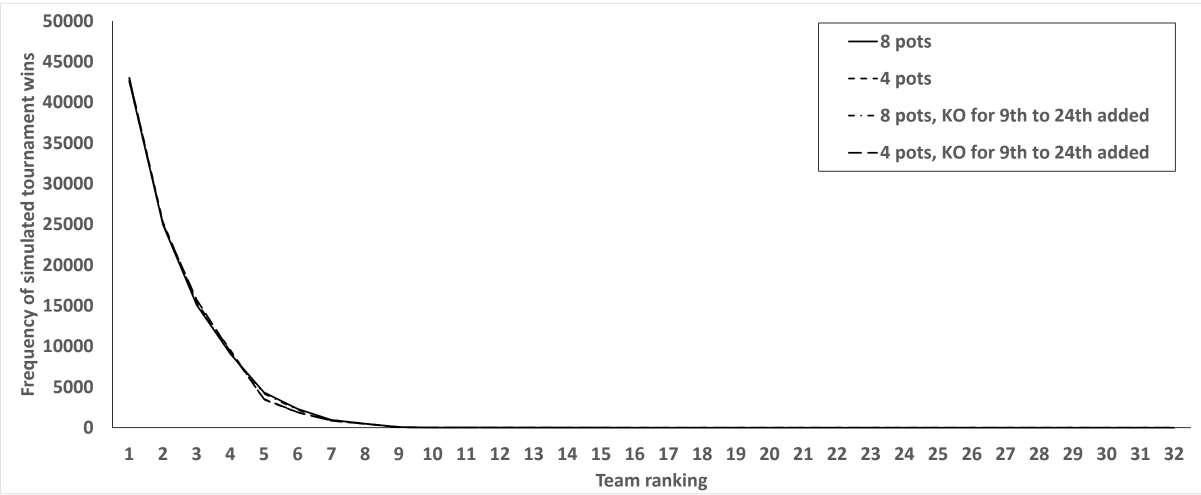

Figure 2. The number of simulated tournaments won by each team.

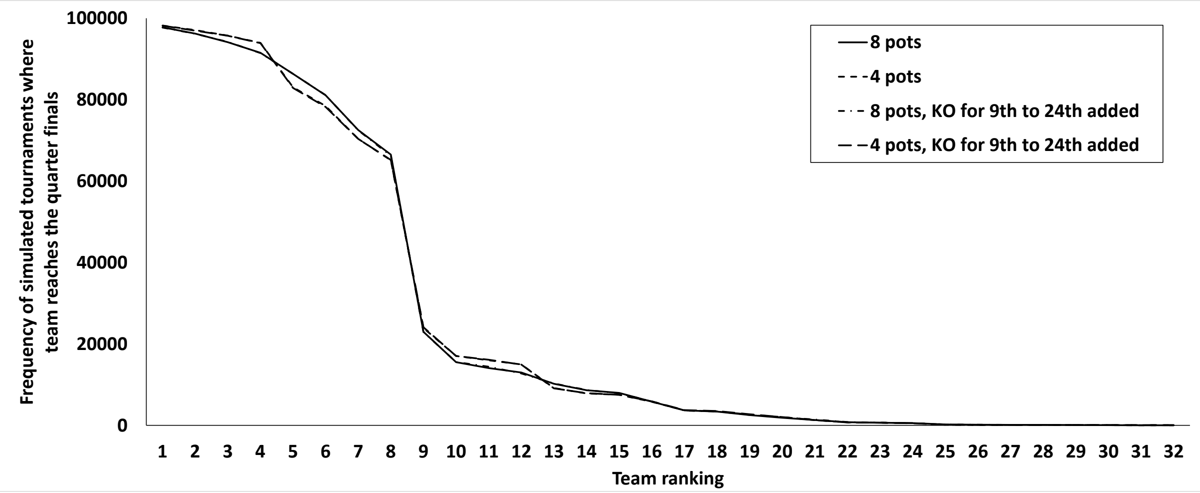

Figure 3. The number of simulated tournaments where each team reached the quarter finals.

Table 1. Number of simulated tournaments where teams of different rankings win and reach the quarter finals (mean for teams in groups rounded to nearest whole number).

Team(s)	Tournament System			
	Eight pots	Four pots	Eight pots, KO for ninth to 24th added	Four pots, KO for ninth to 24th added
To win the tournament				
1	42,643	42,999	42,602	43,003
2	24,952	25,262	25,052	25,044
3 to 4	12,0789	12,459	12,172	12,525
5 to 8	2,019	1,668	1,961	1690
9 to 12	37	33	36	32
13 to 16	6	4	4	4
17 to 24	0	0	0	0
25 to 32	0	0	0	0
To make the quarter-finals				
1	97,785	98,209	97,715	98,186
2	96,218	97,088	96,181	96,953
3 to 4	92,818	94,843	92,799	94,791
5 to 8	76,621	74,247	76,539	74,154
9 to 12	16,392	17,973	16,408	18,050
13 to 16	8,170	7,573	8,195	7,601
17 to 20	2,876	2,964	2895	3,017
20 to 24	826	819	878	807
25 to 28	148	118	150	122
29 to 32	58	62	63	70

Table 2. Tournament metrics for the different tournament systems.

Team(s)	Tournament System			
	Eight pots	Four pots	Eight pots, KO for ninth to 24th added	Four pots, KO for ninth to 24th added
Minimum games for a team	6	6	7	7
Maximum games for a team	9	9	9	9
Total games	112	112	136	136
Average rank of 1st place team	2.61	2.54	2.60	2.53
Average rank of 2nd place team	3.23	3.11	3.22	3.12
Average rank of 3rd place team	3.85	3.63	3.81	3.61
Average rank of 4th place team	4.49	4.19	4.45	4.18
%Wins for highest ranked team	42.64	43.00	42.60	43.00
Expected quality of the final	5.85	5.65	5.82	5.64

Discussion

Figure 1 shows that the chances of teams winning the World Championship are similar between the four tournament systems. This is a desirable situation because the changes to the currently used system were designed to avoid some teams facing more higher ranked teams in the main round than other teams do and situations where teams don't get the opportunity to compete in play-off rounds to secure a higher placing. These problems with the currently used system do not impact on the best team in the tournament because there are no teams ranked higher than them. The simulation suggests that the men's Handball World Cup is more predictable than sports like soccer. All four simulators gave the top team more than a 42% chance of winning the tournament, with the chances of one of the World's top four teams winning the tournament being at least 91%. In soccer, no one team has any more than a 25% chance of winning the men's FIFA World Cup (O'Donoghue et al., 2004). A possible explanation for the greater predictability of international handball is that it is a higher scoring sport than soccer. The higher predictability may also be due to the validity of the HB Statz ranking points. Preliminary analysis using finishing position in the previous World Championship only gave the highest ranked team a 23% chance of winning the tournament. Using ranking alone loses a lot of information about team quality. For example, teams ranked 15 and 16 may be close together or there may be a noticeable gap in their ability. This is not represented by ranking alone. A rating that awards points for international matches and goes beyond merely ranking the teams may have reflected the relationship between team quality and match outcomes better. Such ranking points systems are used in international soccer (FIFA, 2023) and rugby union (Rugby World, 2023). A further issue in representing team quality using finishing position from the previous World Championship is that the 2021 World Championship was played during the Covid crisis with some teams being restricted by the players available for selection as well as restrictions on supporters. In soccer, the absence of supporters reduced home advantage in European domestic leagues during the Covid crisis (McCarrick et al., 2021).

Figure 3 reveals a dramatic drop in teams' chances of making the quarter-finalists after the top eight teams irrespective of whether four pots of eight teams are used or eight pots of four teams. This is explained by the fact that the teams in the top eight all avoid each other in the initial groups while everyone else is drawn against a top 8 team. An additional consideration is that the top eight teams will only have one other team (maximum) from the top eight in their main round group. The rest of the teams making up the main round can expect to have two top eight teams in their main round group. Where pots of eight are used, a team outside the top eight may have to compete in a main round group with two teams in the World's top four teams. For example, in 2023 Slovenia were ranked ninth in the World but had to contest a main round group including France and Spain.

The simulations have revealed that adding an additional knockout stage to determine places nine to 24 makes very little difference to a team's chances of winning the tournament or making the quarter-finals. This makes it difficult to justify any modification that increases the number of games for the teams finishing between nine to 24. Introducing additional games into tournaments brings logistical and practical problems finding venues (Van Bulk and Goossen, 2020). Player welfare is important and the risk of injury needs to be considered when scheduling matches. International handball competition results in 40 injuries per 1,000 hours playing time (Langevoort et al., 2007). This is a higher injury rate than has been observed in other levels of competition and training (Moller et al., 2012). Playing multiple matches over a relatively short period of time may also involve performance decrements. There is conflicting evidence of this from soccer with some research showing physical performance unaffected by multiple matches in the same week (Soroka and Lago-Peñas, 2016) but other research showing a decline in the number of high speed runs and sprints made by players when matches were played fewer than four days after a previous match (Penedo-Jamardo et al., 2017). There may be occasions where teams play each other after differing numbers of recovery days from their previous matches. The men's World Handball Championship minimises the chance of this happening by having teams in the same groups play on the same days. However, half of the teams commence playing in the tournament one day before the other half of the teams. Thus, if two teams commencing the tournament on different days meet in the latter stages, one of the teams will have had to play their previous matches in one less day than the opponent. In international rugby union, having additional recovery days from previous matches over the opponents has been found to be worth 4.1 points in a match when team quality is accounted for (O'Donoghue et al., 2016). Playing additional matches within an international tournament may also be to the detriment of the club sides that players are returning to. In soccer, Bundesliga teams with high numbers of players competing in the 2010 FIFA World Cup were found to under-perform in the first half of the 2010-11 season (Lames and Kolbinger, 2011).

It is easier to justify the use of eight pots of four teams in the draw for the tournament than adding additional matches to determine the teams finishing in ninth to 24th places. There is an argument that teams achieving a World ranking in the top four out of a set of eight teams should gain some reward for this. The increased chances of these teams that results from using eight pots for four teams is explained in two ways. Firstly, the teams ranked from one to four will avoid each other within the main round draw, as will the teams ranked nine to 12. Secondly, teams ranked from nine to 12 will avoid a situation where they progress to a main round group that contains more than one of the World's top four teams. Such a modification to the tournament does not require teams to play any additional matches. Seeding has been found to increase the chances of top performers progressing to the latter stages of tournaments in other sports (McGarry, 2008; Engist et al., 2021). A further possibility in the men's Handball World Championship is to ensure that teams ranked nine to 12 are drawn in the same initial groups as teams ranked five to eight rather than one to four, with the four teams ranked 13 to 16 being drawn against teams ranked one to four. This would add an additional incentive to teams achieving higher World rankings.

The current exercise has compared four versions of the men's Handball World Championship. Other tournaments, such as the Olympic Games, have different numbers of teams and, therefore, the scope of the current investigation is the men's Handball World Championship. The results do not apply to other tournaments. The study also has limitations that should be acknowledged.

The simulations generated fewer draws than are observed in World Championship handball. Home advantage is not addressed by the models and could be a significant factor in international handball; Qatar for example finished runners up in 2015 when they hosted the tournament despite being ranked 28th in the World's at the time. The underlying model of the simulator assumes that team and opposition quality are the only factors predicting performance. Therefore, a limitation of the study is that other factors are not represented.

In conclusion, using eight pots of four teams during the draw for the men's Handball World Championship increases the efficacy of the tournament. There is little additional impact of adding knockout matches to determine places nine to 24. It is recommended that tournament organisers consider using eight pots of four teams during the draw as this has no impact on the number of matches played per team or the total number of matches played in the tournament.here.

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