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Performance analysis of male handball goalkeepers at the World Handball championship 2015

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ABSTRACT: Goalkeepers have a very important role in handball. In coaching communities it is well recognized that goalkeepers' performances can predict team ranking in major tournaments. Despite this, few studies have been conducted on elite goalkeepers participating in World Championships. Therefore, the purpose of this study was to analyse goalkeepers' save performance during the 88 matches of the 2015 men's World Championships tournament. Goalkeepers from 24 national teams were analysed using a tracking camera system and bespoke software (Prozone Handball V.1.2, Prozone, Leeds, UK). The purpose of this study was to examine time-motion performance parameters and to evaluate the save rates for each goalkeeper. The mean total distance covered in a game by the goalkeepers was 1634±999 m. Goalkeepers spent most of the time walking or standing. The total amount of shots to the goal was 6893, with a mean save percentage of 30% (2088 saves). A significant relationship was identified between the goalkeepers' save statistics and the final team rankings. The save rate is important for teams to achieve a higher ranking, and therefore the selection and training of goalkeepers requires more than just assessing physical abilities. The throwing distribution and success/save rate during the Qatar 2015 Men Handball World Championships suggest strong and weak parts of the goal area, and coaches can use this information to adjust their training approaches for both goalkeepers and shooters.

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INTRODUCTION

The International Handball Federation (IHF) organizes the Handball World Championship every two years. The most recent was held in Qatar, 2015 (Men's World Championship). Most performance-related research conducted in handball has focused on the physical requirements of field players, specifically locomotion demands and body contacts [1,2]. Primarily, data from performance analysis from either in situ observations during the game or a review of game recordings have been used to define performance demands and/or player behaviours. Use of such data has been directed to: injuries (27%), physical capacity (18%), physiological variables (13%), and success variables and performance (6%) [3]. Other research has documented distance covered, time spent in different intensity categories, cardiovascular demands, and/or specific strength and power qualities [2,4-6]. Despite the recognition of the importance of goalkeepers in handball, very few studies have been conducted on performance characteristics of elite goalkeepers. The limited studies published on goalkeepers have highlighted that, as expected, they do not cover large running/walking distances [7,8]. The goalkeepers' role is to prevent the opposing team from scoring goals by blocking the ball using the whole body (goalkeepers are allowed to touch the ball with every body part, unlike field players) within the goal perimeter. The most important performance indicators often identified are the 'save' statistics [9]. The percentage of saves and their relationship with the position of the thrower are usually presented as the main indices of performance analysis of goalkeepers [10,11]. Hantâu et al. [12] provided a more comprehensive approach, dividing the goal into eight parts to identify the goalkeepers' saving efficiency with respect to specific parts of the goal while trying to save 7 m throws. Understanding these spatial distributions is key to understanding where shots are aimed and how goalkeepers react [13] and may be used by coaches to improve performance and by opponents to identify weaknesses. A recent analysis of Olympic, World and European tournaments [14] has highlighted the influence of goalkeepers on game results [11].

As goalkeepers play a key role in handball, understanding how they perform during a World Championship could improve training methods, and more detailed analyses of goal-keeping performance can better inform our understanding of their relative contribution to match and tournament success. Therefore, considering the lack of data on elite goalkeepers, the aim of the present study was to analyse the match demands and save performance of the goalkeepers during the 2015 World Championships. The main hypothesis was that goalkeepers of high ranked teams had a better save rate than lower ranked teams. Furthermore, we hypothesized that there was a difference in save rates between the top and lower corners of the goal, with more goals scored at the lower corners as they are the most difficult to reach.

MATERIALS AND METHODS

Participants

Twenty-four teams participated in the World Championships, qualifying from 5 continents (Europe, Americas, Asia, Africa, and South America). Every team played with 2 to 3 goalkeepers on the roster. In total, 54 goalkeepers (age = 30.2 ± 5.2 years, height = 192± 0.05 cm, body mass = 93.7 ± 6 kg, BMI = 25.3 ± 1.4 kg • m^{-2}, 100% right handed) were analysed during the championship. The mean age of all the goalkeepers in the 2015 tournament was 27.9±4.4 years. Handedness was determined based on video footage and defined as the hand they were observed to throw with.

The study was approved by the International Handball Federation, the scientific and medical commission of the 2015 World Championships and the AZF research committee. Video analysis is part of every World Championship, and the International Handball Federation approved the analysis of the videos collected. As players' data were anonymized for the purpose of this study, no individual informed consent was obtained from the players taking part in the tournament.

Experimental design

In total, the teams played 88 matches. Each of the 88 matches played during the World Championships in Qatar was recorded using a setup of 3 cameras (Baumer TXG13c, 1384 x 1036 pixel resolution, 20 fps, Baumer Optronic GmbH, Radeberg, Germany) tripod-mounted with full view and coverage of the handball court. The videos were recorded with bespoke software (Pilotestade V2, ProzoneSports Ltd, Leeds, UK) which created multiple 1 min long videos throughout the capture which were collated using VirtualDub 1.8.6 (software licensed under the GNU General Public License (GPL), http://www.virtualdub.org/download.html), and stored for analysis. An outside broadcast feed was also stored for review but not for tracking the movements of the players. The videos were then analysed to track the players' movement with previously validated methods [15].

Briefly, video files are transferred onto dedicated file servers. The server recognizes the new media and instigates the automatic tracking of the videos. Each video is tracked independently determining image coordinates and continuous trajectories for each player. Once the automatic tracking is completed, the output from all 3 cameras is automatically combined to produce a single dataset. To achieve this, the combination process requires knowledge of the vision's field of view and logic concerning normal player behaviour, i.e. objects must qualify as being of human size, with Kalman filters used to predict the possible direction given the current object speed (Kalman, 1960). At this point, erroneous objects (i.e. sponsors' markings on the court) are filtered out of the dataset. The video's image co-ordinates are converted into world pitch co-ordinates via a calibration process (computer vision homography). Initially, ProZone uses a linear 4-point transformation calibration to map the vision to the pitch co-ordinates and then refine this calibration with a proprietary 50-point algorithm that eliminates vision distortion with respect to optical errors (curvature of the lens) and non-2D playing surfaces (camber of the pitch). Finally, quality control operators identify each player (by start position, position during game and correspondence with the outside broadcast [OB] feed) and verify that the trajectories identified for each player remain constant for that actual player. During periods throughout the game, the trajectory was re-identified on the computer tracking system, checking the movement of each player during the game, and stored on a proprietary file.

From the stored data, the distances covered, time spent in five different intensity categories, and frequency of occurrence for each activity for players in different positions were obtained by specially developed software (ProzoneHANDBALL v1.0.0.14, ProzoneSports, Leeds, UK). The locomotion categories were defined as follows: standing (0-0.9 m • s^{-1}), walking (0.2-1.9 m • s^{-1}), jogging (2-3.9 m • s^{-1}), running 4-5.4 m • s^{-1}), high speed running (HSR; 5.5-6.9 m • s^{-1}) and sprinting (≥7 m • s^{-1}). Additionally, important handball actions during the game were coded: goals scored, shots attempted, area of throws in the handball goal, area of saves in the handball goal.

Attempted throws and blocked shots

558	381	631	Thrown shots
120	*104*	*108*	*Blocked shots*
22%	**27%**	**17%**	**Block rate**
796	383	799	
328	*154*	*278*	
41%	**40%**	**35%**	
1304	511	1433	
328	*146*	*308*	
25%	**28%**	**21%**	

FIG. 1. Attempted throws at the goal, shots blocked by the goalkeeper, and the resulting block rate of the shot represented in percentages.

TABLE 1. Distance, duration (normalized to game time [60 min]), and number of the six locomotion categories (standing, walking, jogging, running, HSR & sprint) of the goalkeepers during the championship (mean ± std).

	Standing	Walking	Jogging	Running	HSR	Sprint
Distance (m)	56.44 ±36.91	1328.94 ± 825.92	220.29 ± 143.51	25.34 ± 34.82	3.27 ± 11.00	0.37 ± 1.52
Duration (60 min)	0.21 ±0.14	0.48 ± 0.29	0.02 ± 0.02	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Occurrences	349.96 ± 218.35	428.51 ± 262.55	82.91 ± 57.12	7.23 ± 8.02	0.88 ± 2.33	0.08 ± 0.30

For the analysis of shots and saves according to the position within the goal, the handball goal was divided into 9 equal parts (3x3 matrix of zones 1 m wide by 0.67 m high, see Figure 1). The numbers of throws and saves in each of these 9 areas were extracted for subsequent analysis.

Shot classification

Shots were classified according to the distance they were performed from (6 m, 7 m for penalties, and 9 m and over for long range shots) or the specific position (wing shots performed by wings), fast breaks (shots performed in a clear fast break action) and breakthroughs (shots performed while in counterattack with 2-5 passes).

In total, 88 matches during the event were analysed, including the preliminary round (60), President's cup (8), placement round (4), and finals (16). To complete the analysis and collect the information on the date of birth and anthropometric characteristics of the goalkeepers, the official statistical data provided by the IHF were used (available online at http://www.ihf.info/en-us/ihfcompetitions/worldchampionships/mensworldchampionships/menshandballworldchampionshipqatar2015.aspx Webpage accessed on 20 Oct, 2016). The number of goals and throw efficiency values were compared to the dataset of the IHF World Championships 2013.

Statistical analysis

Data were visually inspected and checked for normality using the Kolmogorov-Smirnov test. The data were normally distributed, and a one-factor ANOVA with Tukey adjustments for multiple comparison was used to assess the differences in locomotion categories. To understand differences in the save efficiency in different goal areas a chi-square test was performed and the block efficiency was presented in percentages. The Pearson correlation coefficient was used to analyse the association between save performance and team ranking as well as the goalkeepers' age and team ranking. Cohen's approach to describe the magnitude of any relationship identified was used (where r=0.5 is large, r=0.3 is moderate, and r=0.1 is small; Cohen, 1998).

To understand the strength of the relationship between the above-mentioned variables the coefficient of determination was computed to describe the proportion of 'variance' explained by the linear regression. The precision of population estimates was reported as 95% confidence intervals. Statistical significance was set at $P<0.05$.

TABLE 2. Number of shots and goals from each position.

	Shots	Goals	Percentage of goals scored
6 m shots	1595	1043	65%
Wing shots	909	566	62%
9 m shots	3200	1195	37%
7 m shots	697	515	74%
Fast breaks	1161	922	79%
Breakthroughs	704	564	80%

RESULTS

Locomotion performance of goalkeepers

The mean total distance covered in a game by the goalkeepers was 1634±999 m. Goalkeepers spent most of the time walking [$F_{(5,1872)}$585.6 $P<0.001$]; the distance covered for walking was higher compared to e.g. jogging [$F_{(5,1872)}$731.7 $P<0.001$], and goalkeepers very rarely performed any running, HSR, or sprinting [$F_{(5,1872)}$667.7 $P<0.001$] (see Table 1).

Shooting and saves

A total of 8266 shots were made during the tournament, with 6893 shots to the goal and 4805 goals scored (58% of the shots). Excluding shots deflected by the defence (field players), the total amount of shots on goal was 6796, with a mean save percentage of 30% (2088 saves). Shots from over the 9-metre line had the smallest percentage of success, while shots performed during fast breaks and breakthroughs, situations in which the defence is outnumbered and where the attacker has to fight in a one-on-one situation with the goalkeeper, had the highest success (see Table 2).

Shooting and saves performance in specific goal areas

A chi-square test of independence was performed to examine the relationship between throws and the area of the goal. The relationship between these variables was significant, χ^2 (9, N = 6796) = 1531.8, $P = P<0.001$, which suggests that shots were not directed at all zones equally. Specifically, most throws were shot at the lower left corner, followed by the lower right corner (from the perspective of the goalkeeper).

The relationship between these variables (shot location and saves rate) was significant, χ^2 (9, N = 1874) = 379.5, $P<0.001$. Shots directed at the right side of the goalkeeper had a higher save rate compared to the left side. In terms of saving percentage, the middle right side is the area with the highest save percentage followed by the three central areas. The upper left corner seems to be the most difficult place to save the ball (save rate 17%; See Figure 1). Each goalkeeper made 27 ± 5 saves per match and a total of 135 ± 76 saves over the course of the tournament.

Goalkeepers' performance and team ranking

A moderate negative and significant relationship was identified between the goalkeeper save statistics and final team rankings (R^2= 0.4638. $P<0.001$, r=-0.68 (95%CI: -0.85 to -0.38), see Figure 2). This relationship between save rate and ranking explains 46% (strong correlation) of the overall variance in final position (Cohen, 1988).

Teams with a higher percentage of saves are within the first seven teams; France (1st), Spain (4th) and Germany (7th) had the highest save percentage (36%). Within this group, Poland (3rd) had the lowest save percentage, with a mean of 28%. Table 3 also presents

TABLE 3. Blocked shots for each team in percentage and distinguished between the initial shot position/situation. The sparklines at the bottom of the columns use the same scales and depict the association between team ranking and percentage of the particular shot type. Similarly, the sparklines in the right-most column represent a frequency histogram for the individual team, with the bars corresponding to the individual columns (from Total Shots at the left through to Breakthroughs on the far right).

Ranking	Team	Total Shots	6 m Shots	Wing Shots	9 m Shots	7 m Shots	Fast Breaks	Breakthroughs	
1	France	36%	33%	37%	46%	21%	23%	23%	
2	Qatar	33%	37%	27%	58%	30%	28%	9%	
3	Poland	28%	27%	32%	42%	25%	5%	14%	
4	Spain	36%	29%	29%	53%	36%	24%	18%	
5	Denmark	33%	36%	40%	47%	14%	19%	11%	
6	Croatia	33%	25%	30%	49%	11%	13%	9%	
7	German	36%	34%	44%	45%	31%	22%	16%	
8	Slovenia	29%	33%	22%	44%	27%	14%	15%	
9	Macedonia	30%	37%	45%	37%	12%	18%	5%	
10	Sweden	35%	27%	26%	54%	20%	23%	25%	
11	Iceland	31%	34%	36%	40%	30%	12%	17%	
12	Argentina	25%	18%	23%	43%	22%	11%	25%	
13	Austria	32%	28%	38%	45%	32%	17%	10%	
14	Egypt	31%	21%	33%	47%	14%	11%	47%	
15	Tunisia	28%	11%	32%	55%	18%	14%	19%	
16	Brazil	26%	21%	25%	59%	33%	10%	4%	
17	Czech Republic	32%	29%	38%	45%	29%	17%	18%	
18	Belarus	24%	29%	22%	41%	7%	10%	4%	
19	Russia	32%	25%	38%	46%	20%	15%	28%	
20	Bosnia and Herzegovina	28%	29%	17%	39%	19%	18%	24%	
21	Iran	28%	23%	30%	41%	18%	20%	19%	
22	Saudi Arabia	28%	22%	24%	46%	26%	19%	21%	
23	Chile	25%	31%	22%	52%	20%	4%	5%	
24	Algeria	21%	18%	27%	41%	3%	0%	23%	

data for the percentage of saved shots sub-categorised by shot type. Qatar (2nd) and Macedonia (9th), had the highest percentage of saves in 6 m shots. Spain (4th) was the best nation in saving penalty shots. The highest wing shot save percentage was achieved by Macedonia (9th), but they also had the lowest save percentage in 9 m shots.

Influence of goalkeepers' age and height on success rate

No significant relationships were identified between the goalkeeper height (R^2=0.067. *P*=0.220 r=-0.26 (95%CI: -0.60 to -0.16), see Figure 3a) and age on championship success (R^2=0.1366. *P*=0.075 r=-0.37 (95%CI: -0.67 to -0.04), see Figure 3b).

No significant relationship was identified between age and save rate (R^2=0.1202. *P*=0.094 r=0.35 (95%CI: -0.07 to 0.65) see Figure 3c) and height and save rate (R^2=0.1571. *P*=0.053. r=0.40 (95%CI: 0.01 to 0.69) see Figure 3d).

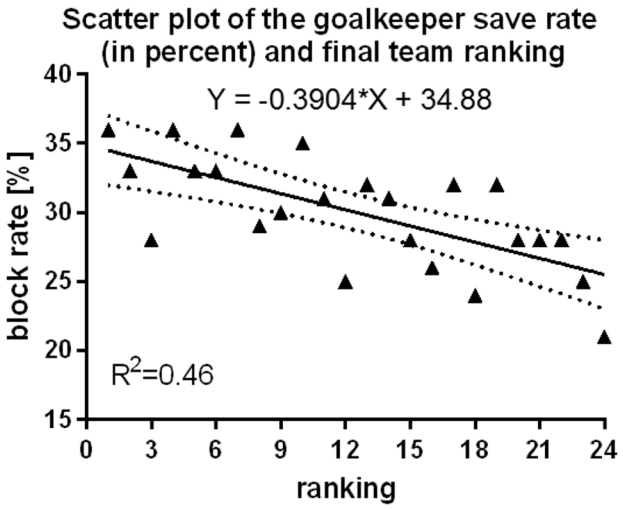

FIG. 2. Teams with a higher block percentage more likely end up within the top ranked teams of the tournament.

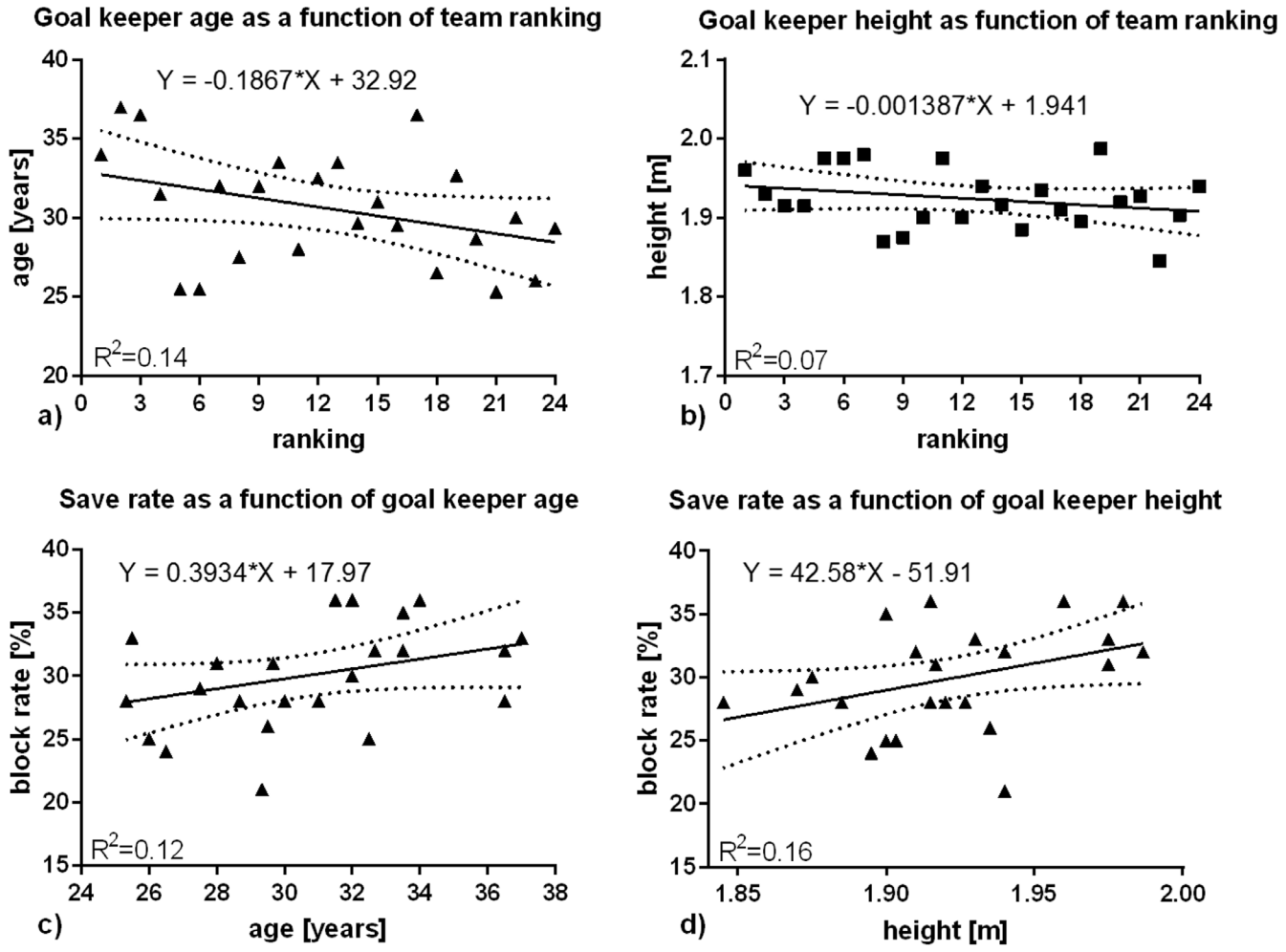

FIG. 3. a) Relationship between goalkeeper's age and final team ranking; b) relationship between goalkeeper height and team ranking; c) relationship between goalkeeper age and block rate; d) relationship between goalkeeper height and block rate.

DISCUSSION

The aim of the present study was to analyse the match demands and save performance of the goalkeepers during the 2015 World Championships. The results of this study on male goalkeepers' performance during the world championship tournament confirm previous findings with regards to the limited distances covered by players in this position [16]. The game demands of goalkeepers are such that limited stresses are likely to be imposed on the cardiorespiratory system [5,8,16]. The low requirements in endurance and running speed during games are also evident when such physical abilities are compared with field players, showing that overall goalkeepers seem to have lower endurance and sprint abilities [17]. Previous research (on Portuguese players of various ages and skill levels) also suggested a lower physical condition of handball goalkeepers when compared to the rest of the handball players in lower limb strength and handgrip [18]. Lower handgrip strength seems common in goalkeepers in both handball and water polo, which appears to be task related [19,20]. In summary, handball goalkeepers have completely different physical requirements from field players and therefore should be trained and selected using different approaches.

Intuitively, it is obvious that taller goalkeepers can cover a larger goal area [21], but also this seems to be a selection criterion considering that goalkeepers are often as tall as backcourt players [22]. The results of our study show no correlations between height and save rate, suggesting that at this level an average height of 192± 0.05 cm may not be an important aspect of goalkeeping performance. The mean age of goalkeepers in the 2015 World Championships was 30.20 ± 5.20 years, which is slightly older than the World Championship in Spain 2013 (28.80 ± 4.82) [22]. Furthermore, the goalkeepers in our study were older compared to all the players (27.87 ± 1.65), suggesting that older age is not a limiting factor for selection, as already identified in Slovenian goalkeepers [23].

It seems evident that when selecting goalkeepers, the importance of physical attributes such as endurance and strength (which may decline with age) possibly less relevant than the perceptual abilities, which may improve with playing experience, and therefore age. Indeed, these results are in accordance with other findings [21,24], as it appears that anticipation is a major contributor to successful goalkeeping, rather than physical fitness [25]. In football these observations have been put into practice, especially in penalty situations [26]. In handball, both young and older goalkeepers initiate their movement before ball release, but compared to the younger goalkeepers, the older goalkeepers wait longer before initiating their movements, resulting in higher block rates [24].

The save percentage during the 2015 World Championship was slightly lower than that observed in the 2013 World Championship (30% compared to 31% (IHF statistics, 2013)) and other international male main events (Olympic Games, World and European Championships) from 2004 to 2010 (35%) [11], possibly suggesting some slight improvements in the shooting abilities of field players.

Areas of higher efficiency and team ranking position

The efficiency of the goalkeepers related to specific areas of the handball goal has been previously reported for 7-metre shots [12]. In contrast to the current study, the goal was divided into eight target areas with the central part where the goalkeeper usually stands before the penalty throw left out. Despite the differences of the game situation, high save rates were also found at the right (28%) and left centre (36%). In the current study the right centre area showed the highest save rate, which may be explained by the goalkeepers' handedness: all goalkeepers in the tournament were right-handed. Previous research did not account for handedness. The results of this study showed the highest save rate on the goalkeeper's dominant (right) side, and the lowest on the low non-dominant (left) side. Future research into shot and save efficiency therefore needs to consider goalkeeper handedness as a confounding factor.

Knowledge of the attacking players' shooting preferences paired with anticipation training may improve the block rate of the goalkeepers [13]. The importance of small changes in this regard can be seen from the work of Fuertes et al. [7], who showed that a 1% improvement in the block rate translates to an increase of 0.57 in the final position ranking, in the first Spanish handball division. Similar results have identified the key role in water polo during the Olympics [27], and in football during the UEFA Champions League [28] and the World Championships [29]. Accordingly, attention to improving goalkeeper performance will likely translate to meaningful team performance enhancement.

Throw efficiency during World Championships

In comparing the 2013 and 2015 World Championships, the main difference in the position shots is observed for the wing shots, with a lower percentage of saves in 2015 (30%) compared to 2013 (35%). However, the number of total wing shots was higher in 2013 (1015) compared to 2015 (909). On the other hand, the 6 m shots showed an increase in 2015 (1595) compared to 2013 (1209), while the rest of the position shots remain similar in both championships (IHF statistics, 2013-2015). These data likely reflect a tournament-specific change of game strategy: national teams tend to play more with pivot players compared to wings at international tournaments, while during national championships the opposite is true [10].

Limitations

During the 2016 season a rule change that allows a faster rotation of the goalkeeper was put in place. The measured physical parameters evaluated in this study would be strongly influenced and probably enhance the physiological demands and consequently the motion analysis of goalkeeping. As this data set was collected prior to this rule change, the results of the motion analysis hold true for teams that do not use constant goalkeeper rotation.

CONCLUSIONS

Save percentage of the goalkeepers showed a moderate to large association with championship success. The top left corner and right middle area of the goal were the highest and lowest successful targets for shooters. Finally, it is evident that the save rate is important for teams to achieve a higher ranking. Therefore the selection and training of goalkeepers requires more than just assessing physical abilities, and it is not limited by age, unlike players in other positions.

Practical implications

The results of this study can be useful in handball training, especially for goalkeepers. Based on the locomotion patterns of the goalkeepers, the training focus should be on perception, anticipation, reaction, and knowledge of the opponent, provided adequate levels of overall fitness are reached. The shot distribution can be used by coaches and technical staff to adjust training approaches. Defensive players and goalkeepers can intensify training in the goal areas with lower block rates while the attacking players train to shoot at the areas with higher scoring rates.

Finally, this study has identified throwing targets during the Qatar 2015 Men's Handball World Championships, suggesting strong and weak parts of the goal area, and coaches can use this information to adjust their training approaches for both goalkeepers and field players.

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