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Playing without goalkeeper: the use of an empty goal in high-performance men's handball

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ABSTRACT

The study aimed to 1) assess the risk of conceding a goal in an empty net; 2) characterise the context when using the empty goal (EG) rule (4:1) in handball and 3) identify the performance variables that influence the EG attacks' efficacy. A total of 974 EG attacks were sampled from 65 matches of the 2022 European Men's Handball Championship. An observational tool was developed to analyse all EG attacks. Frequency analysis and the chi-square test have been performed to analyse the use of EG according to the match context. The binomial logistic regression was used to identify the variables that influence the EG attacks' effectiveness. The results demonstrated that the goalkeeper was replaced mainly to maintain numerical equality. To create offensive superiority, the teams mostly used EG during the last quarter of the match playing under a small score disadvantage. The risk of conceding a goal in the empty net was higher if a team failed to score in previous possession. No relationship was found between the team's final classification and the frequency of EG use, nor the efficacy of EG situations. Two variables have been identified as significant for the 6 × 6 + GK possession outcome: 2nd pivot position and shot zone.

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1. Introduction

A game in any sports tournament is based on a certain number of rules that, by regulating the confrontation, generate a set of principles that restrict the players' behaviour and ensure its rationality. Changing the rules aims to promote a sport by influencing the uncertainty of results, which turns the competitions more interesting to watch and thus more attractive to the media and sponsors (Haugen & Guvåg, 2017). Providing some sort of a new challenge (Vamplew, 2007), the modified rules require the adaptation of teams to overcome the possible arising risks or to benefit from the new opportunities.

In July 2016, a new set of game rules was introduced by the International Handball Federation (IHF) and implemented at the 2016 Rio Olympic Games, attempting to make

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the game more attractive. Among those new regulations, Rule 4:1 began allowing teams to play with an extra field player (FP), without a goalkeeper (GK) (IHF, 2016), thus enabling attacking actions to be carried out with numerical superiority and contributing to their effectiveness (IHF, 2015, p. 11). Playing without GK is commonly known as an empty goal (EG).

The research on the EG use conducted since the implementation of Rule 4:1 (IHF, 2016) shows that elite handball teams mostly replace the GK with a FP to restore numerical equality in situations where one or more players were suspended for 2 min (Bonjour et al., 2021; Flores-Rodríguez & Ramírez-Macías, 2021; Krahenbühl et al., 2021; Krahenbühl, Souza, et al., 2019; Marczinka & Gál, 2018) or to create numerical superiority (7 × 6 + GK) on the pitch. Men's teams use the EG rule more frequently and consistently (Flores-Rodríguez & Ramírez-Macías, 2021; Gümüş & Gençoğlu, 2020; Marczinka & Gál, 2018) than women's teams (Bonjour et al., 2021; Gümüş et al., 2020; Krahenbühl et al., 2021; Trejo-Silva, Feu, et al., 2022; Trejo-Silva, Gomez-Ruano, et al., 2022) in both game scenarios when outnumbered and in numerical equality (Krahenbühl, Souza, et al., 2019). Considerable differences were found between national teams concerning the frequency of EG use to create a numerical advantage (Marczinka & Gál, 2018; Trejo-Silva, Gomez-Ruano, et al., 2022) and the effectiveness of its use (Prudente et al., 2022).

Recent findings suggest that middle and bottom-ranked teams take the risk of playing without GK more frequently than top-ranked teams (Trejo-Silva, Gomez-Ruano, et al., 2022). However, this option depends not only on the team's own quality but rather on the relative strength between two opposing teams (Neuberg & Thiem, 2022).

The research showed that the likelihood of replacing the GK with a 7th player increased in away matches (Meier et al., 2023), especially as the game progressed (Gümüş & Gençoğlu, 2020; Gümüş et al., 2020; Meier et al., 2023; Prudente et al., 2022), and when teams were trailing (Marczinka & Gál, 2018; Prudente et al., 2022; Trejo-Silva, Gomez-Ruano, et al., 2022) at around nine goals or facing stronger opponents (Neuberg & Thiem, 2022).

The results concerning the effectiveness of EG to outnumber the opponents are somewhat contradictory. Some studies reported a lower percentage of success in 7 × 6 + GK comparatively to 6 + GK x 6 + GK attacks (Flores-Rodríguez & Ramírez-Macías, 2021; Krahenbühl et al., 2021; Krahenbühl, Souza, et al., 2019), while others confirmed the higher effectiveness of offensive actions in numerical superiority (Marczinka & Gál, 2018). The increased risk of conceding a goal into an empty net seems to level off the advantage of playing with a numerical advantage 7 × 6 + GK (Neuberg & Thiem, 2022), although some findings have not confirmed that this risk was higher (Prudente et al., 2022).

To better understand the impact of the EG rule on team performance, some studies analysed the tactical patterns that emerge from EG situations. It was reported that playing 6 × 6 with EG teams had longer ball possessions (Korte & Lames, 2019; Prudente et al., 2019), performed more offensive movements with the change of positions were more likely to use distance shots from the central zone, and favoured the success of the opponent's fast break (Flores-Rodríguez & Ramírez-Macías, 2021) compared to the same situation with GK.

In 7 × 6, there were more passes among the first-line players, while in 6 × 6 with EG the game was wider due to the higher involvement of the wing players (Korte &

Lames, 2019). In general, considerable differences have been observed in team patterns of play in the 7 × 6 situations, as well as in the effectiveness of EG use (Prudente et al., 2022).

It is worth mentioning that Rule 4:1 change, which initially generated a lot of controversy (Haugen & Guvåg, 2017; Iusepolsky et al., 2022; Krahenbühl, Menezes, et al., 2019), seems to be progressively accepted by both coaches and players (Iusepolsky et al., 2022; Sousa et al., 2021). This can probably be explained by the coaches' adaptation to the new rule, as seen in the more consistent substitution of a GK with a FP in recent competitions, especially when teams were playing outnumbered (Flores-Rodríguez & Ramírez-Macías, 2021; Krahenbühl et al., 2021; Meier et al., 2023; Trejo-Silva, Gomez-Ruano, et al., 2022).

In conclusion, the research on EG in handball conducted since 2016 has explored the following areas: 1) the reasons behind substituting the GK with a field player, aiming to create numerical superiority or restore numerical equality on the field in both men's and women's handball (Bonjour et al., 2021; Flores-Rodríguez & Ramírez-Macías, 2021; Gümüş et al., 2020; Krahenbühl et al., 2021; Krahenbühl, Souza, et al., 2019; Marczinka & Gál, 2018; Trejo-Silva, Feu, et al., 2022; Trejo-Silva, Gomez-Ruano, et al., 2022); 2) the utilisation of the EG, contingent upon the contextual factors, such as teams' quality, their opponents (Neuberg & Thiem, 2022; Trejo-Silva, Feu, et al., 2022; Trejo-Silva, Gomez-Ruano, et al., 2022), the game location (Meier et al., 2023) and period (Gümüş & Gençoğlu, 2020; Gümüş et al., 2020; Meier et al., 2023; Prudente et al., 2022), and the match status (Marczinka & Gál, 2018; Prudente et al., 2022; Trejo-Silva, Gomez-Ruano, et al., 2022); 3) the assessment of the effectiveness of employing the EG strategy in 7 × 6 and 6 × 6 situations (Flores-Rodríguez & Ramírez-Macías, 2021; Krahenbühl et al., 2021; Krahenbühl, Souza, et al., 2019; Marczinka & Gál, 2018), along with 4) the examination of offensive performance used during exclusions scenarios played without a GK (Korte & Lames, 2019; Prudente et al., 2019; Trejo-Silva, Feu, et al., 2022; Trejo-Silva, Gomez-Ruano, et al., 2022) and finally, 5) the exploration of the evolution of coaches' and players' opinions on the 4:1 rule (Iusepolsky et al., 2022; Sousa et al., 2021).

However, all the studies that have analysed the influence of contextual factors (quality of opposition, game location, or match status) on the EG use have been conducted with the games played in the first two-three seasons after the rule change either in women's handball (Trejo-Silva, Feu, et al., 2022; Trejo-Silva, Gomez-Ruano, et al., 2022) or using samples from men's club teams (Neuberg & Thiem, 2022).

As recent studies have shown, coaches and teams are adapting to the new rule, changing its use and, consequently, the game of handball itself (Iusepolsky et al., 2022; Meier et al., 2023; Prudente et al., 2019, 2022). To better understand how the EG use evolves and how it influences teams' success, further research is needed. Previous analyses of offensive performance in empty net situations have not sought to establish the relationship between performance indicators and the result of the EG attack in elite men's handball. The following analysis should be focused on both, the context in which teams take the risk of playing without a GK and the tactical patterns of play with an empty net. Trying to identify the most effective tactical patterns of play without a GK seems to be particularly useful for the design of training programs that should receive more attention from the coaches (Iusepolsky et al., 2022).

Therefore, the aims of this study were threefold: 1) to characterise the influence of game context on the use of EG in the recent European Championship 2022, one of the most competitive competitions in high-performance men's handball; 2) to quantify the risk of using an empty net and 3) to identify the performance variables that influence the outcome of EG situations. The results of the study are presented and discussed in the same order as the listed goals.

2. Methods

2.1. Data sample

The EG situations from all 65 matches of the 2022 European Men's Handball Championship were analysed from the video footage of the games. Ethics approval was not required as the video footage was publicly available on the official website of the European Handball Federation (EHF), through the EHFTV service (https://ehftv.com/home). A total of 974 attacks played in numerical ratios 7 × 6 + GK and 6 × 6 + GK with EG have been sampled. EG situations with other numerical relations were not considered in the study due to the low frequencies of occurrence.

2.2. Variables and procedures

An observational tool has been developed for this study. The tool was supported by existing notational analysis literature and included several of the variables previously used in handball performance analysis research. Some of these variables were modified to better suit the aims of the study (Freitas et al., 2021; Gomes et al., 2014; Gómez et al., 2014; Lago, 2009; Lago-Peñas et al., 2013; Musa et al., 2017; Oliveira et al., 2012; Prieto et al., 2015; Prudente et al., 2019; Taylor et al., 2008; Teles & Volossovitch, 2015). The observational tool comprised three groups of variables used to characterise EG situations in handball: 1) contextual variables, which describe the competitive situation when the GK was replaced by one of the FPs; 2) performance variables, which are represented by the actions performed during the EG situation; 3) outcome variables, which reflect the result of the EG attack.

The design of the observational tool and the definitions of variables have been validated by three experts in handball performance analysis and coaching. The experts had an average of 29 years of experience in handball coaching, one of them was a national team coach and holder of a Master Coach degree and others were holders of coach level 6/6 of the French Handball Federation and of level 3 of the Portuguese Handball Federation. One expert had a master's degree in high-performance coaching and two others were university professors with a Ph.D. degree in Sports Science.

The definitions of the variables used in the observational tool are presented in Table 1.

After an exploratory data analysis, two of the context variables, *Game period* and *Match status* with low frequencies were reclassified, allowing to satisfy the assumptions of the chi-square test.

The *Match status* at the moment of GK substitution by a FP was classified into four groups by a two-step clustering and *k*-means cluster analysis (Table 1). Two-step clustering using Akaike's Information Criterion was utilised to ascertain the optimal

Table 1. Definitions of variables used in the study.

	Variable	Classes	Definition
Contextual	Team name		Name of the team attacking with EG
	Game period	First half;]30′, 45′];]45′, 60′]	The match period identified according to the time of GK's substitution by one of the field players. The game period initially was classified into six periods of 10 min and reclassified after exploratory data analysis due to the low frequency of EG use in the first 30 min.
	EG duration		The amount of time (in seconds) from the GK's substitution to the end of the EG attack.
	Match status	Balanced positive [0, 2]; Balanced negative [−2, −1]; Moderate disadvantage [−6, −3]; High disadvantage [−13, −7]	Current goal difference at the beginning of the BP with EG.
	Numerical relationship	6×6 + GK; 7×6 + GK	The number of field players of each team at the beginning of the EG situation.
Performance	Start pivot position	1E2; 2E3; 3C3; 2D3; 1D2 (between defenders from left to right)	Positioning zone of the single pivot or the pivot positioned furthest to the left of the attack, at the beginning of the EG situation (Figure 1)
	Start 2nd pivot position	2D3; Other	The second pivot positioning zone, the one positioned furthest to the right of the attack, at the beginning of the EG situation (Figure 1)
	End pivot position	1E2; 2E3; 3C3; 2D3; 1D2 (between defenders from left to right)	Positioning zone of the single pivot or the pivot positioned furthest to the left of the attack, at the end of the EG situation (Figure 1)
	End 2nd pivot position	2D3; Other	The second pivot positioning zone, the one positioned furthest to the right of the attack, at the end of the EG situation (Figure 1)
	NrPivots		Number of pivots at the end of the possession.
	Assist zone	PE; 6E; 6C; 6D; PD; 9E; 9C; 9D; 11+E; 11+C; 11+D	Area of the field where the last pass was performed before the last ball possession (BP) shot on goal (Figure 2)
	Shot zone	Zone 6 m; Zone 9 m; Wings	Area of the field where the last BP shot was performed (Figure 2)
	Defensive system	6:0; 5:1; 3:2:1; Mixed; Individual; Other	Opponent defensive system after reorganization
	GK's return	Ready; Late; Missing	Readiness of the GK when returning to the goal after an EG situation, at the moment of the opponent's shot
Outcome	Attack outcome	Goal; Missed shot; Technical failure; Defensive efficacy; GK's save	Result of BP with EG
	Final result	Win; Draw; Loss	Final match result of the team that used EG
	Goal in empty net	Goal; Missed	The final effect of the actions performed by the opponent's fastbreak, just after the observed attack
	Final ranking		Attacking team ranking at the end of the competition

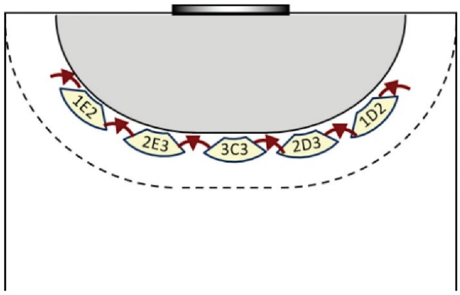

Figure 1. Pivots positioning zones.

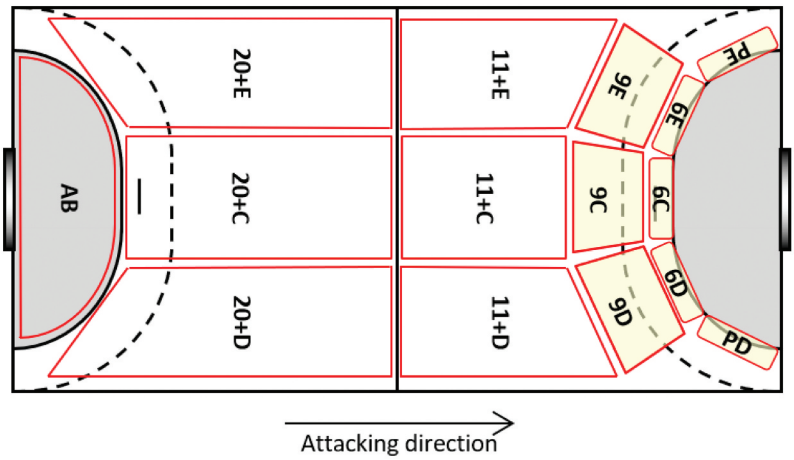

Figure 2. Zones of offensive action.

number of clusters for the *Match status* variable. Subsequently, *k-means* cluster analysis was applied to identify goal differences corresponding to each of the four identified classes within the *Match status* variable.

2.3. Data collection

Data collection was carried out using a registration tool specially designed for this study in the software Microsoft Access 365 (Microsoft Corporation, Redmond, Washington, USA). This tool facilitated data collection increasing its accuracy and consistency. After recording, the data were exported to an Excel file for further analysis. The record of each unit started at the moment when the team in possession proceeded to replace the GK with a FP and finished when the team scored a goal, attempted a field shot without rebound, earned a 7 m throw, performed a technical failure that led to the loss of possession, or when the opposing team intercepted the ball, or when the EG situation modified due to a coach's option, or after changing in the numerical relationship on the field. The gained offensive rebound did not interrupt the recording of ball possesion (BP). The goal scored by opponents in the empty net was also registered to analyse the risk of conceding a goal while playing without a GK.

2.4. Reliability testing

Reliability was assessed from a set of randomly selected six matches including 124 EG attacks (12.7%). Intra-observer reliability tests were conducted by the lead author six weeks after the first data collection to compare the data collected in the 1st and 2nd sessions. A group of three observers, all of them handball players, one master and two graduate students was trained for data collection and then submitted to an inter-observer agreement evaluation process using the data collected by the lead author. Reliability testing was performed using the intraclass correlation coefficient (ICC) computed and interpreted based on a mean rank (number of raters [k] = 4), absolute agreement and two-way mixed effects model (Koo & Li, 2016). The 95% confidence interval of the ICC estimate for the intra- and inter-observer tests ranged from good to excellent reliability, as reported in Table 2.

Table 2. Intraclass correlation coefficient for intra- and inter-observer reliability evaluation.

	Intra-observer				Inter-observer			
		95% Confidence Interval				95% Confidence Interval		
Variable	ICC	Lower Bound	Upper Bound	Reliability Level	ICC	Lower Bound	Upper Bound	Reliability Level
Team name	1.000	1.000	1.000	*excellent*	1.000	1.000	1.000	*excellent*
EG start-time	1.000	1.000	1.000	*excellent*	1.000	1.000	1.000	*excellent*
EG end-time	1.000	1.000	1.000	*excellent*	1.000	1.000	1.000	*excellent*
Match status	.990	.986	.993	*excellent*	.977	.969	.983	*excellent*
Numerical relationship	1.000	1.000	1.000	*excellent*	1.000	1.000	1.000	*excellent*
Offensive system	1.000	1.000	1.000	*excellent*	1.000	1.000	1.000	*excellent*
Start pivot position	.969	.956	.978	*excellent*	.963	.951	.972	*excellent*
Start 2nd pivot position	1.000	1.000	1.000	*excellent*	.979	.964	.988	*excellent*
End pivot position	.953	.925	.969	*excellent*	.967	.954	.976	*excellent*
End 2nd pivot position	.894	.773	.950	*good to excellent*	.924	.871	.958	*good to excellent*
Assist zone	.995	.990	.997	*excellent*	.836	.754	.888	*good*
Shot zone	.977	.963	.985	*excellent*	.963	.946	.975	*excellent*
Defensive system	.960	.940	.973	*excellent*	.93	.905	.948	*excellent*
GK's return	.964	.944	.976	*excellent*	.988	.983	.991	*excellent*
Attack outcome	.985	.978	.990	*excellent*	.988	.983	.991	*excellent*
Goal in empty net	.957	.933	.971	*excellent*	.992	.988	.994	*excellent*
Final ranking	1.000	1.000	1.000	*excellent*	1.000	1.000	1.000	*excellent*

Note. Reliability levels (Koo & Li, 2016): < 0.5 = poor; 0.5–0.75 = moderate; 0.75–0.9 = good; > 0.90 = excellent.

2.5. Statistical analysis

The coded data were transferred from the observation tool and processed using IBM SPSS Statistics for Windows, Version 27.0 software (IBM Corp, Armonk, New York, USA) for all statistical analysis.

To characterise the context of using EG attacks, in the first stage of the study, the descriptive frequency analysis and the chi-square tests were performed. Standardised residuals were calculated to verify associations between classes. Pearson's correlation analysis was used to analyse the association of the team's final ranking with the frequency of EG use and of the team's final ranking with the effectiveness of EG attacks. Successful attacks were defined as those that resulted in a goal or a 7 m throw (Neuberg & Thiem, 2022; Prudente et al., 2022). Effect sizes were calculated with Cramer's V statistic (V), interpreted following Gravetter and Wallnau (2013) and Kim (2017). The significance level was set at $p \leq .05$.

A binomial logistic regression analysis was performed to estimate the probability of successful outcomes in EG attacks according to different sets of independent variables. The dependent variable was the outcome of the EG attack, represented by two classes—successful outcome when the EG attack ended with a goal or a 7 m throw, and unsuccessful outcome for all other situations. To explain the outcome of EG attack, the contextual variables *Game period*, *EG duration*, and *Match status*, as well as the performance variables *End pivot position*, *End 2nd pivot position*, *Assist zone*, *Shot zone*, *Defensive system*, and *NrPivots* were considered.

3. Results

3.1. Frequency and efficacy of attacks without GK

An exploratory analysis of the 65 matches played in the 2022 European Men's Handball Championship has shown that teams used a total of 249 7 × 6 + GK attacks and 725 6 × 6 + GK attacks (when one of the FPs was suspended), 24.1% and 70.1% of all EG attacks, respectively. Since only 60 attacks were played with more than one FP suspended, these situations were not considered in the analysis. Playing without GK to compensate for a suspended player in 725 attacks, teams scored 219 goals (30.2% efficacy) and conceded 89 direct goals in the empty net (12.3% of the attacks). When the teams replaced the GK to create numerical superiority (playing 7 × 6 + GK) they scored 109 goals (43.8% efficacy) from 249 attacks and conceded 29 opponent's goals in the empty net (11.6% of the attacks). It was observed that in a total of 848 attacks initiated with at least one suspension, the national teams played with EG in 785 possessions (92.6%).

EG was used more often to compensate for or reduce numerical inferiority as a consequence of 2-minute player's suspension. However, the effect of contextual variables on the option to play without GK in these situations could not be analysed, because only in 12 situations after a field player suspension teams choose to play in inferiority without replacing the GK (5 + GK x 6 + GK). The same team used nine of these situations in two matches without statistical significance. For this reason, the association between contextual variables and EG situations was analysed only in 7 × 6 + GK.

The number of 7 × 6 + GK attacks used by each team per match varied according to the national team from 0 to 11.7 per game, while the global average per team and game was 1.92 ± 3.64, minimum 0 and maximum 19.

No relationship was found between the team's final ranking and the frequency of EG use ($p = .276$). The same analysis revealed no significant correlation between the final ranking of the teams and their effectiveness in the use of EG situations ($p = .267$).

3.2. The use of 7 × 6 + GK according to the game context

3.2.1. The use of 7 × 6 + GK according to the interactions of match status and game period

Chi-square analysis revealed a significant association with a small effect size between the interaction of *Game period* with *Match status* and the frequency of EG use, $\chi^2(6) = 12.903$, $p = .045$, $V = .165$. A significant positive association was found between the use of EG and the interaction of balanced negative *Match status* and the last 15 minutes *Game period* (Table 3). It means that coaches more often than might be expected by chance opted to replace the GK with one of the field players when the team was losing by at most two goals at the end of the game.

3.3. The risk of conceding a goal in the empty net

To assess the risk of conceding a goal in an empty net, the ratio of the number of GK substitutions per FP and the number of goals directly conceded in the empty net was calculated. From the total sample of EG situations (974), a set of 666 situations was identified as completed attacks (i.e. not interrupted by a change in the number of players or by a 7 m throw). The results of this analysis for both 7 × 6 + GK and 6 × 6 + GK situations are presented in Table 4. A significant association with a medium effect size was revealed by the chi-square test between

Table 3. EG use to create a 7 × 6 + GK situation according to *Game period* crossed with *Match status* - percentage and standardised residual (* significant residual at 5%).

			Match status				
7 × 6 + GK			Balanced positive [0, 2]	Balanced negative [−2, −1]	Moderate disadvantage [−6, −3]	High disadvantage [−13, −7]	N
Game period	First half	% within Game period	18.4%	7.9%	63.2%	10.5%	38
		Standardised Residual	0.4	−1.5	0.7	−0.2	
	]30′, 45′]	% within Game period	16.2%	8.8%	63.2%	11.8%	68
		Standardised Residual	0.1	−1.8	1.0	0.1	
	]45′, 60′]	% within Game period	14.6%	26.2%	47.7%	11.5%	130
		Standardised Residual	−0.3	2.1*	−1.1	0.0	
Total		% within Game period	15.7%	18.2%	54.7%	11.4%	236

EG outcome and goal scored in the empty net, $\chi^2(4) = 118.711$, $p < .001$, $V = .422$.

Table 4. EG attack outcome crossed with opponent's goal scored in the empty net – percentage and standardised residual (* significant residual at 5%).

			Goal scored in the empty net		
			Goal	Missed	N
EG outcome	Goal	% within EG outcome	5.9%	94.1%	324
		Standardised Residual	−5.1*	2.4*	
	Missed shot	% within EG outcome	21.1%	78.9%	71
		Standardised Residual	0.7	−0.3	
	Technical failure	% within EG outcome	29.9%	70.1%	107
		Standardised Residual	3.0*	−1.4	
	Defensive efficacy	% within EG outcome	69.0%	31.0%	42
		Standardised Residual	7.9*	−3.7*	
	GK's save	% within EG outcome	18.9%	81.1%	122
		Standardised Residual	0.3	−0.1	
Total		% within EG outcome	17.7%	82.3%	666

Table 5. *EG outcome* crossed with *GK´s return* status – percentage and standardised residual (* significant residual at 5%).

			GK's return			
			Ready	Late	Missing	N
EG outcome	Goal	% within EG outcome	96.3%	3.1%	0.6%	325
		Standardised Residual	2.4*	−1.0	−5.8*	
	Missing shot	% within EG outcome	88.4%	4.3%	7.2%	69
		Standardised Residual	0.4	0.0	−1.1	
	Technical failure	% within EG outcome	71.8%	4.9%	23.3%	103
		Standardised Residual	−1.4	0.3	3.4*	
	Defensive efficacy	% within EG outcome	19.5%	12.2%	68.3%	41
		Standardised Residual	−4.5*	2.5*	10.6*	
	GK´s save	% within EG outcome	80.8%	4.2%	15.0%	120
		Standardised Residual	−0.4	0.0	1.1	
Total		% within EG outcome	84.0%	4.3%	11.7%	658

3.3.1. Interaction of EG attack outcome and the ability to promptly return the GK to his position

There was a strong significant association with a large effect size between the EG attack outcome and the GK's readiness to return to the empty net, $\chi^2(8) = 195.95$, $p < .001$, V = .39, as shown in Table 5.

3.4. The influence of performance variables on the success of EG attacks

A binomial logistic regression analysis has been conducted separately for 6 × 6 + GK and 7 × 6 + GK attacks. All the simple regression models adjusted for the 7 × 6 + GK situations were not significant ($p > .05$).

Table 6. Parameter estimates of binomial logistic regression of EG result as a function of contextual and performance factors.

Variables/Categories	*B*	Wald	*p*	OR	95% CI
End 2nd pivot position: other vs. 2D3	−1.793	3.884	.049	0.166	[0.028; 0.990]
Shot zone: zone 6 m vs. zone 9 m	−2.757	4.943	.026	0.063	[0.006; 0.721]
Constant	2.969	5.577	.018	19.480	

Note. *B* = Regression Coefficient; *p* = p-value; OR = Odds Ratio; CI = Confidence Interval.
R^2 = .290 (Cox & Snell), .387 (Nagelkerke), model χ2(2) = 3.207, area under the ROC curve = .753.

Two simple regression models with the independent variables *Shot zone* and *End 2nd pivot position*, adjusted for the 6 × 6 + GK situations were revealed to be significant. With these two significant variables in the simple linear regression, a multiple logistic regression model was estimated, and it also showed to be significant. Due to a low number of occurrences, it was necessary to recode the variable *Shot zone* into only two categories (1 - *zone 6 m* and 2 - *zone 9 m*). The results of the binomial logistic regression model estimation are presented in Table 6.

The logistic regression model with the explanatory variables *End 2nd pivot position* and *Shot zone* presents explanatory power R^2 of Nagelkerke = .387 and of Cox & Snell = .290. The value of the area under the ROC curve is .753. The odds ratio (OR) estimates for the two variables are 0.166 for *End 2nd pivot position* and 0.063 for *Shot zone*. Both being less than one means that moving from the reference category (lowest) to the other category influences negatively the chance of moving from failure to success of EG attack. Interpreting the OR in percentage, %OR = 100(OR − 1), it would result in values of −83.4% for *End 2nd pivot position* and −93.7% for *Shot zone*. Thus, moving from the reference zone of *End 2nd pivot position* (0-other) to zone 1 (2D3) decreases the chance of success relative to failure by 83.4%; while moving from the reference zone of *Shot zone* (zone 6 m) to the zone 1 (zone 9 m) decreases the chance of success relative to failure by 93.7%.

To better understand these findings, a frequency analysis was used crossing the data of variables *End 2nd pivot position*, *Shot zone* and *Attack outcome*. The results revealed that, in general, the number of 6 × 6 + GK situations with two pivots was low, which limits extrapolations of the results. However, it was observed that the second pivot, when positioned between the first and second defenders, provided more effective shots from the 9 m zone. It can be supposed that a more decentralised positioning of the second pivot allows for creating more space near the centre zone and better conditions for back-court players' shots.

4. Discussion

4.1. Frequency and efficacy of attacks without GK

As might be expected, the results demonstrated that in high-performance modern handball, the GK is most often replaced by a FP to compensate for a previously suspended player. From 848 possessions initiated with at least one suspension, 93% were played with the EG. This result is in line with those reported in previous studies. For instance, Bonjour and co-authors (2021) have recorded the use of the EG in 84.4% of all attacks after a player's exclusion in matches of the 2018–2019 Women's EHF Champions League. Flores-Rodríguez and Ramírez-Macías (2021) found that teams played in the 2019 Men's

Handball World Cup replaced GK with a FP in 17.1% of the total 445 analysed ball possessions, and chose to play with EG in 100% of 57 numerical inferiority situations, 55 (96%) of which were 6 × 6 + GK. It is worth mentioning that the analysis of matches from the 2016 Rio Olympic Games Men's Handball competition, which was the first event where the new EG rule has been implemented, revealed that 144 of a total of 841 attacks were played with EG, of which in 85 (59%) the GK has been replaced to maintain the numerical equality in the attack (Krahenbühl, Souza, et al., 2019). These results confirm the teams' adaptation to the new rule which led to the near extinction of numerical inequality situations in modern handball since in most of them the GK is replaced by one of the FPs to compensate for the suspended player. It seems obvious that teams are more effective when playing on equal terms rather than outnumbered, which was confirmed by Komar et al. (2019), who analysed 85 games played in the 2017/2018 French National League and found that the probability of scoring a goal in numerical equality was 33%, while on numerical inferiority it was only 20%.

4.2. The use of EG according to the game context

Several studies have evidenced the importance of considering the influence of competitive context on team performance in handball match analysis (Gómez et al., 2014; Gómez-Ruano, 2017; Oliveira et al., 2012; Teles & Volossovitch, 2015; Volossovitch, 2008).

The analysis has shown that the 7 × 6 + GK situations were used more frequently in the last 15 minutes of the match when teams played with a small scoring disadvantage (one or two goals). These results are similar to those obtained in other recent competitions and corroborate the more frequent use of GK substitutions by FP to create numerical superiority in the later periods of the game if the teams were at a disadvantage (Marczinka & Gál, 2018; Neuberg & Thiem, 2022; Prudente et al., 2022; Trejo-Silva, Gomez-Ruano, et al., 2022).

Teles and Volossovitch (2015) reported a significant impact of the balanced *Match status* in the last minutes of the handball game on the teams' behaviour and coaches' decisions. The last minutes of the game, associated with the scenarios of balanced *Match status*, are considered critical moments in the high-scoring games to which handball belongs (Ferreira et al., 2014; Lozano et al., 2016; Oliveira et al., 2012; Teles & Volossovitch, 2015). Thus, our study confirms that 7 × 6 + GK can be considered as one of the solutions for those moments of the game which are highly likely to influence the match outcome and potentially can be classified as critical. In these situations, especially in score-disadvantage scenarios, some coaches tend to risk more (Neuberg & Thiem, 2022), using the "all or nothing" principle and replacing the GK with a FP. Furthermore, it seems that the greater the heterogeneity between the opposing teams, the more likely the weaker team is to use the seventh player (Neuberg & Thiem, 2022).

Our results did not establish any significant relationship between the team's ranking and the frequency and effectiveness of EG usage. However, the limited number of games played by weaker teams and the infrequent use of 7 × 6 situations by some teams hindered our ability to analyse how differences in team rankings influence the frequency and effectiveness of EG deployment. Therefore, future research should utilise larger

Table 7. Goals scored in the empty net as a function of the EG attack outcome.

Outcome of EG attacks	N	Goals scored in EN	Relative
EG attacks ended without a shot	149	61	40.9%
EG attacks ended with a saved or missed shot	193	38	19.7%
EG attacks ended with a goal	324	19	5.9%

samples than the restricted pool of national teams that participated in the 2022 European Men's Handball Championship.

It is interesting that previous research has revealed a low effectiveness of 7 × 6 + GK attacks except for the case of the Portuguese national team in the 2020 European Championship matches (Prudente et al., 2022). So, further research is needed to better understand how different national teams use the GK substitution by a FP and what team behaviours contribute to the efficacy of 7 × 6 + GK attacks in different match contexts.

4.3. The risk of conceding a goal in the empty net

In EG situations in handball, teams conceded goals only 17.7% of the time, with outcomes significantly associated with the previous attack's result (Table 7). Attacks ending without a shot had a 40.9% goal concession rate, compared to 19.7% for attacks with unsuccessful shots and 5.9% for successful goals. Substituting a field player with a goalkeeper reduced the risk of conceding a goal in the empty net, but losing possession increased it. In the 2019 Men's Handball World Championship, opponents scored in 21.1% of EG attacks. These findings highlight the importance of effective attacks in EG situations, stressing the need for shots on goal and goalkeeper substitution training.

4.3.1. Interaction of EG attack outcome and the ability to promptly return the GK to his position

In most cases, the GK returned to his own goal in time after his team scored while playing with EG. But this return was considerably compromised when the team lost the BP due to technical failure or efficient opponents' defensive actions. It should be noted that 30% of the technical failures and 70% of the effective defensive actions resulted in scoring goals in the empty net.

4.4. The influence of performance variables on the success of EG attacks

Using logistic regression, we tried to identify the successful patterns of play which led to scoring in EG attacks. For this analysis, the data of all national teams played in the 2022 European Men's Handball Championship was used.

The model estimated for the 6 × 6 + GK situation revealed two variables with significant influence on the probability of scoring or earning a 7 m throw when a team was playing with EG – the positioning zone of the 2nd pivot at the moment of the shot and the shooting zone. It was observed that when the second pivot was positioned between the first and second defenders, shots from the 9 m zone were more effective in 6 × 6 + GK situations. As expected, these findings show that teams playing in a risky situation with an EG, should try to shoot from the most effective court areas, where the chances of success are higher, and that, apparently, a more decentralised positioning of the pivot creates better conditions for the back-court players to score.

Perhaps due to the particularities of play of the different teams, the diverse frequencies of the EG use, and because of great number of tactical options, it was not possible to find a pattern of successful behaviours for the 7×6 + GK situations using logistic regression analysis. Perhaps an analysis according to the specific team would allow for finding an effective pattern of play without GK, referring to that team.

Our results somewhat corroborate the findings of previous studies regarding the higher level of participation by wing and pivot players in 6×6 attacks with EG (Korte & Lames, 2019) and greater mobility of wing players, where one of the wingers circulated to the 2nd pivot position (Flores-Rodríguez & Ramírez-Macías, 2021; Prudente et al., 2019). However, none of these studies sought to establish the relationship between performance variables and the outcome of EG attacks.

Therefore, identifying the most effective tactical patterns in EG situations requires further investigation, especially given the evolving nature of handball. Teams continuously adapt to rule changes, modifying their offensive and defensive behaviour in EG situations. This adaptation is also evident in the changing opinions of coaches and players regarding the EG rule (4:1), which is increasingly accepted (Iusepolsky et al., 2022; Sousa et al., 2021).

It has been suggested that the 4:1 rule can make the game more predictable (Haugen & Guvåg, 2017). This is another reason to continue studying the behaviour of teams playing with an empty net.

Thus, our study aimed to bridge the knowledge gap regarding the utilisation of the EG strategy in high-performance handball. We addressed a range of issues that have not yet been elucidated in the scientific literature or have only been examined in older competitions. Specifically, our findings shed light on the variability in EG usage based on the game context, characterised by game time (*Game period*) and current goal difference (*Match status*). The study also explored the correlation between the risk of conceding a goal in an unguarded net and the offensive effectiveness of the team playing without a goalkeeper. Additionally, it identifies the performance variables that influence the success of attacks carried out without a goalkeeper, as well as clarifies how the utilisation and effectiveness of EG attacks correlate with the final team ranking in the tournament.

5. Conclusions

5.1. Frequency and efficacy of attacks without GK

In high-performance handball, a GK is replaced mainly to compensate the excluded FP and less often to create numerical superiority in the attack. Our findings demonstrated that in 93% of all possessions initiated with at least one player suspended, the teams replaced the GK with a FP.

The average frequency of GK substitution by a FP to create numerical superiority varies according to the national team from 0 to 11.7 times per game, the global average per team and per game was 1.92, minimum 0 and maximum 19.

Table 8. Effectiveness in 7 × 6 + GK and 6 × 6 + GK attacks from studies on EG situations.

Competition	Matches	Teams	Efficacy 7 × 6 + GK		Efficacy 6 × 6 + GK	
			Goals/Attacks	Rel.	Goals/Attacks	Rel.
2017 IHF World Championship (Marczinka & Gál, 2018)	15	Group C: 6	32/98	32.7%	50/194	25.8%
2020 EHF European Championship (Prudente et al., 2022)	28	Top 12	68/123	55.3%	N/A	N/A
2022 EHF European Championship	65	All 24	109/249	43.8%	219/725	30.2%

Note. N/A = Not available.

As shown in Table 8, an analysis of teams' performance in EG situations may suggest a trend of improvement over time. For instance, during the 2017 World Championship, the effectiveness of 7 × 6 + GK attacks was 32.7% and for 6 × 6 + GK attacks, it was 25.8%. Subsequently, at the European Championship, these values increased to 55.3% in 2020 and 43.8% in 2022 for 7 × 6 + GK, and to 30.2% in 2022 for 6 × 6 + GK attacks. However, this analysis is limited by the different types of competitions (World and European Championships), the reduced samples of teams and matches analysed in the 2017 and 2020 competitions (Marczinka & Gál, 2018; Prudente et al., 2022) and the restriction to one group of the preliminary round (Marczinka & Gál, 2018). Therefore, it is necessary to further investigate this topic to obtain meaningful results on the effectiveness of EG.

No relationship was found between the team's final classification and the frequency of EG use ($p = .276$), nor the efficacy of EG situations ($p = .267$).

5.2. The use of EG according to the game context

The match context influences the coach's decision to create numerical superiority by replacing the GK with a FP. The situation 7 × 6 + GK was used more frequently in the last 15 minutes of the match, especially when teams were playing with a small score disadvantage (losing by one or two goals).

5.3. The risk of conceding a goal in an empty net

It has been found that the risk of conceding a goal in an empty net was very low (19 occurrences or 5.9%) after a goal was scored in the previous possession by the team that played without GK. However, this risk increased considerably (99 occurrences or 28.9%) when the team playing without GK lost the ball.

A strong association has been found between the EG attack outcome and a GK's readiness to return to a goal. The high attack effectiveness of the team playing with EG can be seen as an inhibiting factor for the opponent's attempt to score in an empty net.

5.4. The influence of performance variables on the success of EG attacks

Perhaps due to the teams' inequitable use of the 7×6 + GK situation and the tactical particularities of their play, the conducted analysis did not allow us to identify any performance variable that significantly influenced the result of an EG attack when a team playing in a 7×6 + GK situation.

Two variables, *End 2nd pivot position* and *Shot zone*, have been identified as significant for the 6×6 + GK possession outcome. In EG attack the 2nd pivot should be placed outside the central field zone and the shot should be executed from areas close to the goal to ensure the success of the team playing without GK.

5.5. Limitations of the study

Among the limitations of the present work, it should be mentioned the following: the lack of information about the total number of ball possessions per match, which could allow a comparison of the effectiveness of attacks played with and without GK; the use of data from an international competition with relatively few matches compared to domestic league championships; the use of a cross-sectional analysis (applied to different teams), which may not be the most appropriate for studying the tactical options of the teams.

5.6. Suggestions for future research

To better understand the feasibility of using the EG situations, it is necessary to: 1) analyse domestic league matches from one or more entire seasons; 2) to include in the analysis other contextual variables, such as game location and game importance; 3) to use a more balanced sample in terms of the number of matches played by each team at different stages of the championship; 4) to use in the analysis not only discrete notational variables but also players' positional variables; 5) to analyse the context of the use of a GK replacement and the patterns of play in these situations according to the team and 6) to extend the study of EG use to women's handball.

5.7. Recommendations for practice

Since the empty goal is a possible solution for the game's critical moments, the offensive and defensive exercises in 7×6 + GK situations should be included in the training process. To take advantage of playing without GK, it is crucial to enhance the team's capability to generate shooting opportunities, improve shooting accuracy, and facilitate the swift return of the goalkeeper to the goal. This objective relies not only on tactical preparation but also on the physical attributes of the goalkeeper, including their acceleration capacity.

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References

Bonjour, C., Tortajada, D. A., Dol, G., & Gonzalez, A. (2021). Repercusiones defensivas del ataque sin portera en el balonmano femenino europeo de élite (defensive repercussions of the attack without a goalkeeper in European elite womens handball). *Retos*, *2041*(40), 413–418. https://doi.org/10.47197/retos.v0i40.82232

Ferreira, A. P., Volossovitch, A., & Sampaio, J. (2014). Towards the game critical moments in basketball: A grounded theory approach. *International Journal of Performance Analysis in Sport*, *14*(2), 428–442. https://doi.org/10.1080/24748668.2014.11868732

Flores-Rodríguez, J., & Ramírez-Macías, G. (2021). Portería vacía: Su influencia en el campeonato mundial de balonmano masculino 2019. *Revista Internacional de Medicina y Ciencias de la Actividad Fisica y del Deporte*, *21*(84), 591–606. https://doi.org/10.15366/rimcafd2021.83.011

Freitas, R., Volossovitch, A., & Almeida, C. H. (2021). Associations of situational and performance variables with defensive transitions outcomes in FIFA world cup 2018. *International Journal of Sports Science and Coaching*, *16*(1), 131–147. https://doi.org/10.1177/1747954120953666

Gomes, F., Volossovitch, A., & Ferreira, A. P. (2014). Team timeout calling in handball. *International Journal of Performance Analysis in Sport*, *14*(1), 98–110. https://doi.org/10.1080/24748668.2014.11868706

Gómez, M. Á., Lago-Peñas, C., Viaño, J., & González-Garcia, I. (2014). Effects of game location, team quality and final outcome on game-related statistics in professional handball close games. *Kinesiology*, *46*(2), 249–257.

Gómez-Ruano, M. A. (2017). La importancia del análisis notacional como tópico emergente en Ciencias del deporte. *RICYDE Revista Internacional de Ciencias del Deporte*, *13*(47), 1–4. https://doi.org/10.5232/ricyde2017.047ed

Gravetter, F. J., & Wallnau, L. B. (2013). *Statistics for the behavioral sciences* (9th ed.). Cengage Learning.

Gümüş, H., & Gençoğlu, C. (2020). The effects of the goalkeeper substitution rule as a new strategy in handball: Analysis of Men's European handball Championship 2020. *Acta Gymnica*, *50*(3), 113–121. https://doi.org/10.5507/ag.2020.015

Gümüş, H., Şahin, T., & Gençoğlu, C. (2020). Additional field player tactics' effects to match performance during the numerical asymmetric situations in female handball. *Turkish Journal of Sport and Exercise*, *22*(2), 305–310. https://doi.org/10.15314/tsed.753048

Haugen, K. K., & Guvåg, B. (2017). Uncertainty of outcome and rule changes in European handball. *European Journal of Sport Studies*, *1*(1). https://doi.org/10.12863/ejssax6x1-2018x2

IHF. (2015). *IHF council meeting 6*. https://www.handball.no/globalassets/nhf-sentralt/om-oss/organisasjon/protokoller/ehf-og-ihf/ihf-council/2016-ihf-council-minutes-nov.pdf

IHF. (2016). *Rules of the game: Indoor handball*. https://www.ihf.info/sites/default/files/2019-07/New-Rulesofthe GameGB.pdf

Iusepolsky, R., Morgulev, E., & Zach, S. (2022). The "empty-goal" rule change from the perspective of international-level team handball goalkeepers. *International Journal of Environmental Research and Public Health*, *19*(11), 6506. https://doi.org/10.3390/ijerph19116506

Kim, H.-Y. (2017). Statistical notes for clinical researchers: Chi-squared test and Fisher's exact test. *Restorative Dentistry & Endodontics*, *42*(2), 152. https://doi.org/10.5395/rde.2017.42.2.152

Komar, J., Chaigneau, A., & Bonifay, T. (2019). L'Infériorité Numérique en LNH, Faut-il Vraiment Sortir son Gardien de But? *Approches Du Handball*, *170*, 33–38.

Koo, T. K., & Li, M. Y. (2016). A guideline of selecting and reporting intraclass correlation coefficients for reliability research. *Journal of Chiropractic Medicine*, *15*(2), 155–163. https://doi.org/10.1016/j.jcm.2016.02.012

Korte, F., & Lames, M. (2019). Passing network analysis of positional attack formations in handball. *Journal of Human Kinetics*, *70*(1), 209–221. https://doi.org/10.2478/hukin-2019-0044

Krahenbühl, T., Menezes, R. P., & Leonardo, L. (2019). Elite coaches' opinion about the additional court player and the strategic-tactical structures in handball. *Motriz: Revista de Educação Física*, *25*(3), Article e101931. https://doi.org/10.1590/S1980-6574201900030008

Krahenbühl, T., Pereira, L. L. L., Menezes, R. P., Amazonas, S. M. F., & Leonardo, L. (2021). Effect of using the additional field player on attack efficiency during 2017 women's handball world championship. *Acta Gymnica*, *51*, Article e2021.007. https://doi.org/10.5507/ag.2021.007

Krahenbühl, T., Souza, N. P. D., Leonardo, L., Galatti, L. R., & Costa, G. D. C. T. (2019). The use of the additional field player on handball: Analysis of the rio 2016 Olympic Games.[El uso del jugador adicional en el balonmano: Análisis de los juegos olímpicos de río 2016]. *RICYDE Revista Internacional de Ciencias del Deporte*, *15*(57), 295–306. https://doi.org/10.5232/ricyde2019.05707

Lago, C. (2009). The influence of match location, quality of opposition, and match status on possession strategies in professional association football. *Journal of Sports Sciences*, *27*(13), 1463–1469. https://doi.org/10.1080/02640410903131681

Lago-Peñas, C., Gómez, M. A., Viaño, J., González-García, I., & De Los Ángeles Fernández-Villarino, M. (2013). Home advantage in elite handball: The impact of the quality of opposition on team performance. *International Journal of Performance Analysis in Sport*, *13*(3), 724–733. https://doi.org/10.1080/24748668.2013.11868684

Lozano, D., Camerino, O., & Hileno, R. (2016). Análisis del comportamiento táctico ofensivo en momentos críticos de juego en el alto rendimiento en balonmano: Un estudio Mixed Methods. *Cuadernos de Psicología del Deporte*, *16*(2), 151–159.

Marczinka, Z., & Gál, A. (2018). The chain reaction between the media and sport. The impact of rule changes in handball. *Physical Culture and Sport, Studies and Research*, *80*(1), 39–47. https://doi.org/10.2478/pcssr-2018-0024

Meier, H. E., Jetzke, M., & Terwolbeck, A. (2023). Industry hierarchy in team sport industries, team tactics and competitive advantage: The empty goal option in league handball. *European Sport Management Quarterly*, *23*(5), 1587–1609. https://doi.org/10.1080/16184742.2022.2048045

Musa, V., Modolo, F., Tsuji, G., Barreira, C., Morato, M., & Menezes, R. (2017). Participação do goleiro-linha no handebol: Análise a partir do tempo de jogo, relação numérica, posto específico e match status. *Revista Portuguesa de Ciências do Desporto*, *2017*(S1A), 213–221. https://doi.org/10.5628/rpcd.17.s1a.213

Neuberg, L., & Thiem, S. (2022). Risk-taking in contests with heterogeneous players and intermediate information—evidence from handball. *Journal of Sports Economics*, *23*(7), 851–880. https://doi.org/10.1177/15270025211071028

Oliveira, T., Gómez, M., & Sampaio, J. (2012). Effects of game location, period, and quality of opposition in elite handball performances. *Perceptual and Motor Skills*, *114*(3), 783–794. https://doi.org/10.2466/30.06.PMS.114.3.783-794

Prieto, J., Gómez, M. Á., & Sampaio, J. (2015). Players' exclusions effects on elite handball teams' scoring performance during close games. *International Journal of Performance Analysis in Sport*, *15*(3), 983–996. https://doi.org/10.1080/24748668.2015.11868845

Prudente, J. N., Cardoso, A. R., Rodrigues, A. J., Mendes, J. N., Fernando, C., Lopes, H., & Sousa, D. F. (2022). Playing 7 vs. 6 with an empty goal: Is it really an option for coaches? A comparative analysis between Portugal and the other teams during the Men's European handball championship 2020. *Frontiers in Psychology*, *13*, Article 809909. https://doi.org/10.3389/fpsyg.2022.809909

Prudente, J. N., Cardoso, A. R., Rodrigues, A. J., & Sousa, D. F. (2019). Analysis of the influence of the numerical relation in handball during an organized attack, specifically the tactical behavior of the center back. *Frontiers in Psychology*, *10*(2451), 1–7. https://doi.org/10.3389/fpsyg.2019.02451

Sousa, D., Cardoso, A., Rodrigues, A., Lopes, H., Fernando, C., & Prudente, J. (2021). Team handball and empty goal (7 vs. 6) rule-the coaches' perception. *6th EHF Scientific Conference*, 149–153. https://www.eurohandball.com/media/tg3dxns2/ehf-scientific-conference-2021.pdf

Taylor, J., Mellalieu, S., James, N., & Shearer, D. (2008). The influence of match location, quality of opposition, and match status on technical performance in professional association football. *Journal of Sports Sciences*, *26*(9), 885–895. https://doi.org/10.1080/02640410701836887

Teles, N., & Volossovitch, A. (2015). Influência das variáveis contextuais no desempenho das equipes nos últimos 10 minutos do jogo de handebol. *Revista Brasileira de Educação Física e Esporte*, *29*(2), 177–187. https://doi.org/10.1590/1807-55092015000200177

Trejo-Silva, A., Feu, S., Camacho-Cardenosa, A., Camacho-Cardenosa, M., & Brazo-Sayavera, J. (2022). Relation of offensive performance during exclusions and final ranking in female handball. *Applied Sciences (Switzerland)*, *12*(21), Article 10774. https://doi.org/10.3390/app122110774

Trejo-Silva, A., Gomez-Ruano, M. A., Feu, S., & Brazo-Sayavera, J. (2022). Analysis of offensive performance during exclusions in female senior handball. *International Journal of Performance Analysis in Sport*, *22*(5), 684–700. https://doi.org/10.1080/24748668.2023.2180881

Vamplew, W. (2007). Playing with therules: Influences on the development of regulation in sport. *The International Journal of the History of Sport*, *24*(7), 843–871. https://doi.org/10.1080/09523360701311745

Volossovitch, A. (2008). *Análise dinâmica do jogo de andebol. Estudo dos factores que influenciam a probabilidade de marcar golo* [Unpublished doctoral dissertation]. Universidade Técnica de Lisboa.