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Measures of tactical efficiency in water polo

Abstract: We present a notational analysis of offensive tactics commonly employed in elite men's water polo and address three questions related to this objective: which tactics are most effective?, which tactical performance indicators best classify the winning team?, and how accurate are predictive models based on these performance indicators? We define a new statistic, Efficiency Rating, which quantifies the importance of a tactic via a weighted average of direct and indirect goals generated by its use. By this measure, direct shot is the most efficient even strategy despite being employed far less frequently than centre or perimeter tactics. We address our second question by measuring the effect size of winning over losing teams for 25 tactical variables and find that exclusion conversion rate is the most effective discriminatory statistic in both close and unbalanced games, correctly classifying almost 90% of all contests. To address our third question, we develop and apply a simple Binomial model based on goals generated per play which correctly predicts all eight games in the medal round of the 2012 Men's Olympics from preliminary rounds. Success probabilities are computed based on a weighted average of offensive and defensive efficiency with an optimal weight that favors defense.

Keywords: classification; notational analysis; prediction; water polo.

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Introduction

The sport of water polo holds a prominent place as the first team sport introduced into the Olympics over 100 years ago. While the study of physiological, biomechanical, and anthropometric factors involved in the sport dates back half a century, statistical analysis of tactical efficiency and related performance indicators has a less developed history. Enomoto et al. (2003) presented the first set of potential performance indicators which included number of attacks, number of shots, ratio of shots to attacks, shooting percentage, personal fouls, offensive "mistakes," and attack duration. These statistics were computed for high and low ranking teams participating in the FINA (Fédération Internationale de Natation) World Championships to identify key indicators of team success. Around the same time, Lozovina, Pavii, and Lozovina (2004) laid a foundation for the study of player movement and physical load related statistics. Later studies examined the technical and tactical aspects of water polo games, considering specific offensive (Lupo et al. 2010; Argudo Itturriaga et al. 2011) and defensive (Argudo Itturiaga et al. 2007; Lupo, Condello, and Tessitore 2012a; Lupo et al. 2014) play situations, swimming stroke (Hughes et al. 2006), tactical roles (Lupo et al. 2012b), game outcome (Argudo Itturriaga et al. 2009; Lupo et al. 2011), different codes (Lupo et al. 2009), and international rules (Platanou et al. 2007).

Despite this increase in interest from sports scientists and data analysts, typical box scores for water polo contests track only basic player statistics such as goals, shots, steals, blocks, and fouls, providing little information about tactical efficiency. In fact, to the best of our knowledge, there are no academic papers which provide a complete list of offensive tactics commonly employed by coaches in the sport and compare team or game by game performance in said tactics. Our goal here is to lay an academic foundation for the notational analysis of offensive tactics in the sport of water polo by presenting new techniques for tracking and examining game data from this perspective. The primary questions we seek to answer are: (i) what are the most effective offensive tactics employed in water polo?, (ii) which tactics exhibit significant differences in performance indicators for winning and losing teams?, and (iii) how can such performance indicators be used to predict the outcome of future contests? In regard to (ii), we also contrast the discriminatory power of performance indicators in close vs. unbalanced games where we define a *close game* as one which is decided by three (the median score differential in our sample) or fewer goals.

The discriminatory analysis we use to address (ii) is similar in spirit to the recent studies of Lupo et al. (2012a, 2014), Escalante et al. (2011, 2012, 2013). However, our work differs from these investigations in that we focus specifically on tactical analysis. The game logs in our sample contain information about the tactical choices and outcomes associated with each play in the contest. As a consequence, we are able to examine offensive tactics in greater detail than previous studies and develop new statistical measures to assess the efficiency of these tactics. Our paper is further distinguished from other studies in our development of two simple probabilistic models for predicting the outcome of future contests. We conclude by applying these models to predict the outcome of the 2012 Men's Olympic playoff rounds using team data from the preliminary rounds of play.

Methods

Sample

The sample for our study consisted of game tapes from 45 elite men's water polo matches, including 16 games from the 2011 European Championships and Qualifying Rounds, six from the 2012 Dublin Cup, and 23 from the 2012 London Olympics. Overall, there were 27 close and 18 unbalanced games in our sample with five of the close games resulting in ties. Games were filmed from mid-court by the first author (European Championships and Dublin Cup) and representatives from USA water polo (Olympics). While camera position varied, all twelve players and the defending goalie were kept in frame at all times. The first author later watched the recorded tapes to transcribe play by play game logs summarizing each tactic attempt and the associated outcome.

Variables and definitions

In order to address our three research objectives, we begin by defining some basic statistics which we will use to assess the efficiency of offensive tactics. A *play*[1] is defined as a particular offensive tactic executed by the team currently in control of the ball. Twelve different tactics are considered including eight even situations, counterattacks, and three power-play game situations (see Table 1). Detailed descriptions of each tactic can be found in the Appendix. Plays can end in one of eight different outcomes, listed here in order of desirability for the offensive team. Names have been chosen in line with previous studies considering such parameters where appropriate (Lupo et al. 2012a, 2014).

Table 1 Overall distribution of offensive tactics used in our sample. Full descriptions of tactic classifications are contained in the appendix.

Category	Play	% of Attempts	% of Plays
	Perimeter	15	22
	Direct shot	8	7
	Centre	22	30
Even	Drive	17	4
Tactics	Post Up	3	2
	Pick	<1	<1
	New centre	<1	<1
	Double centre	1	1
Even Totals		67	65
Counterattacks		12	10
Power-play	4–2 PP	19	22
Tactics	3–3 PP	<1	<1
	Quick	2	3

1. *Goal* – play ending in a scored goal.
2. *Penalty Shot* – a major foul is committed within the 5-m line resulting in a penalty shot for the offensive team.
3. *Exclusion* – a major foul is committed outside the 5-m line resulting in a 20 s exclusion of one defensive player and a six on five power-play advantage for the offense.
4. *Corner* – the ball is knocked out of bounds by the goalkeeper resulting in a return of possession to the offense with the resetting of the clock-time action (i.e., 30-s clock-time are provided for each possession).
5. *Rebound* – a shot is attempted and is blocked by a defensive player or rebounds off the goalpost, but the offensive team regains possession of the ball.
6. Offensive Foul – an offensive player commits a major foul, resulting in a change of possession.
7. *No Goal Shot* – a shot is attempted and blocked, but the defensive team gains possession of the ball.
8. *Lost Possession* – the defensive team gains possession as a result of a steal, blocked, or dropped pass.

We also track tactic *attempts*, which in addition to plays, include situations in which a particular tactic was attempted, but did not result in a measurable outcome. We call the latter scenarios *unexecuted attempts*. For example, if a player without the ball drives towards the goal, but does not receive possession of the ball, this would count as an unexecuted drive attempt, but not a play. Overall,

1 In basketball, it is common to distinguish between plays and *possessions* (Kubatko et al. 2007), the latter referring to the period of game play between which a team gains control of the ball until the time at which control passes to the opposing team. In this paper, we look only at plays because (i) we are more interested in the outcome of specific tactical choices and (ii) the proportion of plays ending in non-possession ending outcomes such as corner or rebound is relatively small anyways.

our sample contained a total of 6476 attempts including 4481 plays and 1995 unexecuted attempts.

From Table 1, we can see that about 65% of all plays involved even tactics, 25% involved power-play tactics, and 10% involved counterattacks. These numbers appear to be roughly consistent with Figure 5 in Lupo et al. (2012a), which is based on data from the 2009 World Men's Championship. An overwhelming majority of even plays (80%) resulted from perimeter or centre tactics with direct shots accounting for an additional 11%. Approximately one out of every four even attempts was a drive, but this tactic made up only a small fraction of all plays because 85% of all drives resulted in unexecuted attempts. Table 2 compares the distributions of outcomes for the three most commonly used even tactics and counterattacks.

In previous studies, tactical efficiency has most commonly been measured by shooting percentage (Enomoto et al. 2003; Escalante et al. 2011, 2012) or in some cases, by the percentage of play attempts ending in favorable outcomes Lupo et al. (2012a). However, as shown in Table 3, almost 60% of all goals in our sample resulted from power-play or penalty situations, suggesting that the efficiency and relative importance of any tactic should be measured by a weighted average of direct and indirect goals generated by its use. We define three new statistics which will be used to assess tactical efficiency based on this averaging principle. The first, which we call the Efficiency Rating of tactic i, is defined by the formula

Table 2 Distribution of outcomes for the four most commonly used even tactics and counterattacks.

	Counter	Perimeter	Direct Shot	Centre
Unexecuted attempts	44	2	45	4
Missed Shots	16	52	23	8
Goals	11	15	9	3
Rebounds	<1	<1	<1	<1
New Clocks	2	8	3	1
Exclusions	16	9	11	42
Penalties	1	<1	<1	2
Offensives	4	2	5	16
Turnovers	6	11	4	24

Table 3 Overal % breakdown of goals scored.

	# of Goals	% of Total
Even	257	29.8%
Counterattack	91	10.6%
Power-play	462	53.6%
Penalty	52	6%
Total	862	

$$ER_i = \frac{G_i + \pi P_i + \varepsilon E_i + \eta R_i}{T_i} \quad (1)$$

where

- G_i is the number of direct goals scored from tactic i.
- P_i is the number of penalty shots generated by tactic i.
- E_i is the number of exclusions generated by tactic i.
- R_i is the number of rebounds and corners generated by tactic i (i.e., second chance opportunities).
- T_i is the total number of plays using tactic i.
- π is the Penalty Shooting Percentage (PSP)
- ε is the Exclusion Conversion Rate (ECR) defined by

$$\varepsilon = \frac{\text{exclusion goals} + \pi \times \text{penalty shots from exclusions}}{\text{exclusion opportunities}}.$$

(In other words, ε is the probability that an exclusion opportunity results in a direct or indirect penalty shot goal).[2]

η is the overall Even Efficiency Rate (EER) defined by

$$\eta = \frac{\text{even goals} + \varepsilon \times (\text{even exclusions}) + \pi \times (\text{even penalties})}{\text{even plays} - (\text{rebounds} + \text{corners})}.$$

The Efficiency Rating for a particular tactic can be thought of as the probability that running the tactic will result in a direct goal or indirect goal via a power-play, penalty, or new even opportunity. To explain this connection, we note that the probability of scoring a goal after running a particular tactic is

$$P(\text{Goal}) = P(\text{Goal}) + \varepsilon P(\text{Power} - \text{play}) + \pi P(\text{Penalty} + \eta P(\text{New Even Opportunity}).$$

which is the same as eq. (1). A cautious reader may also question our definition of the EER: why do we exclude rebounds and corners? The reason is similar to the calculation of odds in the casino game of craps: the probability of rolling a six before a seven, for example, is

$$\frac{p(6)}{p(6)+p(7)} = \frac{5}{11}.$$

Here, we are thinking of a new even opportunity as a round of craps: a team will maintain possession until they either lose possession of the ball or score a goal. The

2 We exclude exclusions resulting from exclusions in this calculation so that ε is technically the conditional probability that a power-play situation results in a goal given that the power-play resulted in a return to an even situation or counterattack.

probability of scoring a goal before turning the ball over is then

$$\frac{p(Goal)}{p(Goal)+p(Loss)}$$

which is the definition of η. As a more mathematical explanation, we are modeling an even possession as a Markov chain with three states: maintaining possession, scoring a goal (directly or indirectly), and losing possession. The latter two are absorbing states so the probability of ending up in the goal scoring state agrees with the definition of η (see, for example, Chapter 4 in Durrett (2009)).

Estimates of ε, π, η along with 95% (Clopper-Pearson) confidence intervals are included in Table 4. For back of the envelope computations, one could also use the rough estimates $\pi \approx 0.9$, $\varepsilon \approx 0.5$, and $\eta \approx 0.25$, as these values are well within the corresponding confidence intervals for each parameter value.

Note that the parameters π, ε, and η are universal parameters, meaning, that they are computed using the combined results of all contests in our sample. When comparing teams, however, exclusion and even conversion rates can be highly variable, and hence ER_i does not measure the relative importance of tactic *i* in an individual team's game plan and cannot be directly interpreted as an individual team's success probability in running tactic *i*. We therefore define two additional statistics to compare team usage of tactics: Goals Generated per Play (GGP) and Fraction of Goals Generated (FGG). FGG_i is a direct measure of the relative contribution of tactic *i* to a games final score. The *FGG* score for tactic *i* is calculated by

$$FGG_i = \frac{\text{Goals Generated by } i}{\text{Total Number of Goals Scored}}.$$

On the other hand, GGP_i is defined in the same way as ER_i except that individual team conversion rates are used in place of π, ε, and η. Therefore, a team's GGP for a particular tactic can be interpreted as the probability that the team will generate a goal from using the tactic. To illustrate the difference between GGP and ER, suppose that in a contest between Teams *A* and *B*, *A* generates four goals and eight exclusions in 16 centre plays with an exclusion conversion rate of 0.25 while *B* generates three goals and six exclusions in the same number of plays with an exclusion conversion rate of 0.5. The first team used the centre tactic more efficiently and hence, receives a higher ER for their centre play. However, both teams ultimately generated the same number of goals from the position and hence, centre played an equally important role in each team's game plan. For our purposes, we will use ER to isolate and assess the importance of individual tactics in winning games while we will use GGP to predict goals generated by tactic use. Note that a team's overall offensive GGP rating is similar to the statistic Offensive Efficiency Rating which is commonly employed in basketball (Kubatko et al. 2007) except that GGP is presented as a probability while Offensive Efficiency Rating is presented as a ratio (points to possessions).

Table 4 Estimates of conversion rates.

	Estimate	95% confidence interval
π	0.87	(0.75, 0.94)
ε	0.48	(0.44, 0.51)
η	0.24	(0.23, 0.26)

Statistical analysis

To address our second research objective, we applied classification based techniques with the binary response variable Win/Loss and 25 tactic-related variables (see Table 6 for a comprehensive list) as potentially relevant performance indicators. We did not include measures of efficiency for less commonly employed offensive tactics due to small sample sizes. Five of the 45 games which resulted in ties were excluded from this analysis since a tie is beneficial to both teams. While discriminatory analysis of game data typically looks at winning and losing team statistics as independent variables, applying two-sample *t*-tests (Lorenzo et al. 2010), ANOVAs (Lupo et al. 2012a), χ^2 statistics (Escalante et al. 2011, 2012), or more sophisticated data mining methods (Delen et al. 2012) to assess discriminatory power, we instead focused here on examining individual game differences in our explanatory variables. The disadvantage of this approach was a reduction in sample size: 40 games instead of 80 individual team measurements on each statistic. The advantage is that we were able to quantify the importance of obtaining the higher value at a particular performance indicator as opposed to the importance of obtaining a particular value of the performance indicator. We also believe that since opposing team statistics in an individual game are indeed dependent variables, such dependency should be taken into account in calculating effect sizes and *p*-values.

Variables which showed a significant impact on game outcome were identified in two ways. First, we defined a *percent advantage* for each explanatory variable as the conditional percentage of games in which the winning team ended with a higher value, given that one team ended with a higher value. For example, if the winning team's value of a given performance indicator is greater than the losing team's value in five of eleven games, but the two teams receive the same mark in one game, this particular variable receives a percent advantage of 50%. The justification for defining percent advantage as a conditional percentage is that a tie in a particular statistic represents a neutral impact on the outcome of the game; the importance of the statistic should then be determined by how often it led to a victory when a difference was observed. Also note that most variables[3] did not have a large number of ties and hence, the conditional percentage was approximately the same as the overall percentage of contests in which the winning team gained an advantage. We used conditional Binomial Tests to identify percent advantages which significantly differed from 50%. Explicitly, a *p*-value was computed by

$$2\min(P(X\geq x_{observed}), P(X\leq x_{observed}))$$

where X is Binomial random variable with success probability 0.5 and n=40 – # of games in which the two teams recorded the same value. This is equivalent to a Wilcoxon-Sign Test in which ties are ignored (Dixon and Massey 1951). In addition to percent advantage, we applied two-sided, paired *t*-tests to the average differences between winning and losing teams in each performance indicator. Effect sizes for each performance indicator were measured by the percent advantage and the standardized Cohen's d statistic

$$d=\frac{\overline{x}_{win}-\overline{x}_{lose}}{s}$$

where s is the standard deviation of all 40 game differences. Wilcoxon-Signed Rank Tests for nonzero medians were also performed to confirm significant results and no discrepancies were observed.

To compare close and unbalanced games, we performed only nonparametric tests because of the small sample sizes associated with each type of game. Conditional Binomial Tests were used to assess the significance of the percent advantages and Wilcoxon Signed-Rank tests were used to determine if the median advantage was significantly non-zero in close games. Mann-Whitney *U*-Tests were applied to assess differences between the role played by performance indicators in close vs. unbalanced games.

3 Exceptions included penalty shots and shooting percentage for centre and direct shots, which all received values of 0 for both teams in about 40% of contests in our sample.

Results and discussion

Tactical efficiency

To address our first objective, efficiency ratings for the three most commonly used even tactics and counterattacks are summarized in Table 5 along with the corresponding shooting percentages and a measure of risk we call the *Turnover Percentage*. Turnover percentage was computed as the percentage of plays resulting in a direct change of possession via a missed shot, an offensive, or a loss of possession outcome. Comparing the four tactics, perimeter had the lowest ER and shooting percentage coupled with the highest turnover percentage (although the latter is mainly due to the large number of missed shots –80% of the turnovers from perimeter). Interestingly, direct shot yielded an ER and shooting percentage of five points higher than perimeter shooting, a moderately significant difference (χ^2=2.27, p=0.10).

The overall distribution of goals generated by tactic was similar for winning and losing teams with no significant differences between the two (χ^2=3.18, p=0.79). This suggests that on average, winning and losing teams in elite men's water polo are generating their goals in the same ways and that the "winning edge" cannot be explained by looking at play distribution. The next section examines other potentially significant performance indicators.

Game by game analysis

Table 6 summarizes the statistical analysis of our 25 tactical related explanatory variables. Notice that there are only three statistics which showed a significantly negative mean advantage: turnover percentage, drive attempts, and

Table 5 Statistical comparison of the most commonly used offensive tactics. Note that GGP and ER yield identical results for the combined data set. Overall shooting percentages are also similar to ER, but exhibit a great deal more variation on a game by game basis; see Table 6.

	Counter	Peri.	DS	Centre	Overall
Attempts per game (single team avg)	8.86	11.14	5.85	15.49	56.72
Plays per game (single team avg)	5	10.89	3.24	14.88	37.24
Shooting%	38%	20%	25%	26%	22%
Turnover%	46%	67%	59%	50%	55%
ER (GGP)	0.36	0.22	0.27	0.26	0.26
FGG	0.18	0.22	0.09	0.41	1

Table 6 Winning team advantages for tactic related performance indicators. Total Goals is included as a frame of reference for interpreting the relevance of effect sizes.

Statistic	Winning team mean	Mean Diff	Cohen's d	Median Diff (Q1, Q3)	Percent Adv.
Total Goals	11.48	3.45	1.65	3.00 (2.00, 5.00)	100
Overall GGP	0.30	0.09***	1.27	0.08 (0.03, 0.12)	93***
PP Goals	5.78	1.48***	0.77	2.00 (0.00, 3.00)	86***
ECR	0.58	0.18***	0.96	0.17 (0.05, 0.32)	85***
Even Goals	4.80	1.55***	0.45	1.00 (0.25, 1.75)	79***
Pe SP	0.24	0.09**	0.49	0.08 (0.02, 0.19)	78***
Pe ER	0.25	0.06*	0.39	0.07 (0.00, 0.14)	75**
Quick Plays	1.58	0.65**	0.54	0.00 (0.00, 2.00)	75*
DS SP	0.27	0.13	0.31	0.00 (0.00, 0.33)	74*
Penalties	0.90	0.38	0.31	0.00 (0.00, 1.00)	70
CA Goals	1.30	0.55*	0.35	1.00 (−0.75, 1.00)	69*
CA ER	0.41	0.09*	0.34	0.09 (−0.06, 0.25)	68*
EER	0.27	0.03**	0.43	0.03 (−0.02, 0.08)	68*
CA SP	0.44	0.22**	0.43	0.25 (−0.19, 0.57)	68
Cen Plays	15.33	1.28	0.27	2.00 (−3.00, 4.00)	63
CA Plays	5.35	0.90	0.27	1.50 (−1.75, 3.00)	56
DS ER	0.28	0.04	0.11	0.00 (−0.16, 0.27)	55
Cen SP	0.22	0.02	0.04	0.00 (0.00, 0.22)	55
Total Plays	37.43	0.33	0.08	0.00 (−2.00, 3.00)	50
Cen ER	0.26	−0.01	−0.10	0.00 (−0.09,0.05)	46
Turn%	0.50	−0.03*	−0.36	−0.03 (−0.09, 0.04)	38
Drives	10.6	−3.33*	−0.43	−2.00 (−7.75, 1.75)	35*
Pe Plays	10.55	−1.08	−0.21	−2.00 (−5.00, 3.00)	35
Exclusions	10.40	−0.75	−0.25	−1.00 (−3.00, 1.00)	35
Unexecuted	18.13	−3.25*	−0.35	−3.00 (−8.00, 3.75)	33
DS Plays	2.98	−0.58	−0.20	−1.00 (−2.00, 2.00)	31*

For mean differences and percent advantages, * indicates results with p-value <0.05, ** indicates p-value <0.01, and *** indicates p-value <0.001.

unexecuted attempts. In the case of turnovers, it is surprising that the mean (and median) difference is only 3%, with the winning team having a higher turnover rate in 38% of contests. Furthermore, the significance of the mean difference in turnover percentage disappeared when we considered only turnovers and offensive fouls so that missed shots alone accounted for the advantage here. In the case of unexecuted and drive attempts, the differences were more pronounced and on a related note, the losing team ended up with more perimeter and direct shot plays in a large fraction of contests as well. There are two possible explanations for these discrepancies: either attempting more plays, drives, direct shots, and/or perimeter plays is detrimental to a team's chances of winning a contest (i.e., these tactical choices have a causal effect on a team's chances of winning) or losing teams are forced into more attempts, drives, direct shots, and/or perimeter plays because of superior defensive play on the part of the winning team. While the latter is the more likely explanation, further research into this question is warranted to confirm this hypothesis.

There is one other statistic worth mentioning as favoring the losing team even though it did not show a significantly nonzero mean difference: in 24 of 37 games, the losing team received more exclusion opportunities. A closer look at exclusions revealed that there was a weak negative correlation (ρ=−0.21, F=2.17, p-value =0.15) between the exclusion difference and margin of victory. Despite the lack of statistical significance, this negative correlation is still practically significant because given the importance of exclusion goals, one would expect a positive correlation with margin of victory. We hypothesize that the negative correlation may be due to referee bias: some referees tend to call an even number of fouls against both teams, slightly favoring the losing team in unbalanced games. This hypothesis is further backed up by the fact that the negative exclusion differential is one per game less in close games than in unbalanced games and the fact that seven of the top eight Olympic teams (and all of the top six) had average exclusion differentials of one per game or fewer (see Tables 9 and 10).

After discussing statistics which favored the losing team, we move on to discuss statistics which demonstrated a positive advantage. While centre and counterattack plays tended to slightly favor the winning team, the more significant advantages occurred in measures of efficiency and obviously, goals scored. Perhaps the most striking feature of our game by game comparisons was the magnitude of the winning team advantage in exclusion conversion rate: on average, the winning team converted 18% more power-play situations than the losing team (58% vs. 40%) and had a higher ECR in 33 of the 40 games.[4] Power-play goals were even in roughly one out of four games, but in about half of the games, the winning team obtained two or more power-play goals than the losing team. *Quick* is a particular power-play tactic in which the offensive team takes an immediate shot at the goal. In such situations, the conversion rate was especially high (56% overall) and the winning team attempted a significantly greater number of such plays than the losing team.

The winning team scored more even goals in three out of four games, but the effect size for this performance indicator was only moderate (d=0.43). The most significant efficiency advantage for even tactics occurred in perimeter shooting where the winning team had a better shooting percentage and ER in almost four out of five games. Counterattacks yielded larger mean differences in efficiency rating than any even tactic, but results were also more variable leading to similar effect sizes as perimeter. Interestingly, there was no significant difference in centre ER, with the losing team actually obtaining a slightly higher value. Direct shot was too little used to observe any significant differences, despite the large difference in average shooting percentages between winning and losing teams.

Before moving on to our close game analysis, we pause to compare our results on shooting percentage with those found in Escalante et al. (2012) for women's water polo. In their paper, they classify games according to round of play: preliminary, classification, or medal round. Our counterattack shooting percentages and exclusion conversion rates are roughly consistent with values at all stages, but our centre shooting percentages are much lower. For example, we estimate a mean shooting percentage of 22% for winning teams while they estimate a mean of 49% for their first two rounds and 35% for the last round. Furthermore, we estimate a small and insignificant difference of only 2% between winning and losing teams while they estimate differences ranging from 27.5% in the preliminary rounds down to about 6% in the medal rounds. It would be interesting to know if the discrepancy represents a true difference in men's and women's performance or if obtaining more preliminary matches on the men's side would yield similarly large shooting percentage disparities between winning and losing teams.

Close game analysis

There were five performance indicators which tended to yield significantly different effect sizes in close and unbalanced games; see Table 7. The fact that the overall GPP advantage was significantly smaller in close games is not surprising given that the number of plays for winning and losing teams was similar. It is also not surprising that the median even goal differential was twice as large in unbalanced games although it is somewhat surprising that the winning team only won the even battle in 13 of 22 close games as opposed to 17 of 18 unbalanced games. Still more intriguing, however, is the fact that power-play goals did not exhibit the same significant difference in effect size between close and unbalanced games. In fact, the percent advantage for power-play goals was roughly the same for both types of contests (85% and 87.5%, respectively).

Another striking characteristic of our close vs. unbalanced game comparisons is that the median difference in EER was 0 for close games, essentially meaning that winning and losing teams were equally likely to be more efficient in overall even offense during close contests. Given the importance of centre play in the sport, one might suspect that a team must at least gain an advantage in this tactic to win close games, but comparison of centre ERs showed that the losing team was usually more efficient at centre in close contests. The same negative differential in centre ER was not present in unbalanced games. Even if we account for differences in ECR by looking at centre GGP instead, the winning team only received a slight median advantage of 0.01 in close games. To highlight the insignificance of this effect size, we note that it amounts to a difference of only one goal in 100 plays.

Table 8 shows factors which exhibited significant effect sizes in close games. We already discussed the

Table 7 Statistics demonstrating a significant difference in effect size between close and unbalanced games.

Statistic	Median diff (close)	Median diff (unbalanced)
Overall GGP***	0.04	0.13
EER**	0	0.08
Even Goals**	1	2
Cen ER*	−0.02	0.02
Cen GGP*	0.01	0.15

4 There was also one game in which both teams had the same ECR.

Table 8 Statistics which showed a significant differential in close games.

Statistic	Median (Q1, Q3) Diff	Percent advantage
Overall GGP	0.04*** (0.01, 0.07)	86***
ECR	0.09** (0.05, 0.25)	86***
PP Goals	0.5* (0,3)	85*
Quicks	0* (0, 1.25)	77
Cen ER	−0.02*(−0.1, 0)	32

difference in centre ER and power-play goals. It is also obvious why overall GGP is present at the top of our list. More interesting is the fact the ECR was won or tied by the winning team in just as many close games (19 out of 22) as overall GGP with a median difference of more than 0.09. With an average of 11.5 exclusions per game, this amounts to an advantage of about one exclusion goal per game. Further down the list, one sees that the winning team also executed significantly more quick plays than the losing team in close games. However, the difference in quick tactics was not enough to account for the overall difference in exclusion rates for close games; even after we excluded quick plays, winning teams had a significantly better ECR.

Is the large effect size from ECR related to better overall shooting by the winning team? To investigate this relationship, Figure 1 shows the relationship between the differences in exclusion conversion rates and even shooting percentage for all close games. The correlation between the winning team advantages in these two categories is significantly negative (r=−0.59, p-value=0.003)[5] suggesting that higher differences in exclusion rates actually corresponded to smaller differences in even shooting percentage.

The importance of converting exclusions is not surprising, but our data set seems to suggest an even greater impact on the outcome of contests than previous studies. We believe this is because previous analysis has focused on using data from typical water polo box scores which track exclusion goals only when a goal is scored within 20 s of the time at which an exclusion is called. But in the reality of a water polo match, there is often a 3–5 s lag time between the end of a 20 s exclusion and the time it takes the excluded player to swim back into a defensive position. In our analysis, we counted any goal scored before the game actually returned to an evenly matched situation as an exclusion goal. To assess the importance of including such goals and confirm the importance of ECR in elite men's water polo, we looked at data for the 2013 FINA World Championships (the first major tournament in a new "quad" of water polo contests leading up to the 2016 Olympics) obtained from www.omegatiming.com. Using Omega Timings's exclusion conversion rate (X goals/Personal Fouls) we obtained correct classifications in 29 out of 40 (72.5%) games from this tournament, but only 13 of 20 (65%) close contests. However, after including all goals scored within 25 s of the start of the exclusion, we correctly classified 82.5% of all games and 80% of close games.

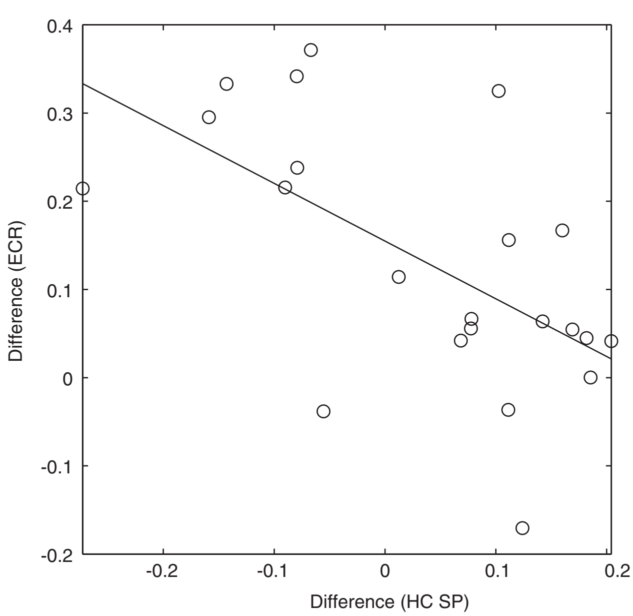

Figure 1 Plot of ECR vs. Even shooting percentage for close games along with the corresponding regression line.

Olympic predictions

Tables 9 and 10 compare the opening round performance of the eight playoff teams from the 2012 Olympics on both offense and defense.[6] Teams are listed in order (first to eighth) of final tournament ranking.

Looking at offensive statistics, we observe that although the distribution of goals generated by tactic was fairly consistent on a game by game basis, it exhibited a greater degree of individual team variability. For example, Serbia generated 17% of their goals from direct shots while Hungary only generated 3% from this tactic. Italy made the least use of perimeter shooting while most other teams

5 The correlation is similar if one looks just at perimeter shooting percentage.

6 We excluded all games against last place finishers Kazakhstan and Great Britain as well as the Serbia vs. Romania game because it occurred after Romania was eliminated from playoff contention.

Table 9 Offensive team comparisons.

Offense	CRO	ITA	SRB	MNE	HUN	ESP	AUS	USA
Plays per Game	37.75	38.75	39.33	37.5	35.75	37.75	39.25	37
Exclusions	10.25	11.50	10.33	11.75	11.25	9.00	9.00	9.00
ECR	0.53	0.46	0.55	0.49	0.68	0.44	0.42	0.39
Quick	2	1.5	2.67	1.5	2.25	0.75	1.25	1.5
CA FGG	0.16	0.23	0.17	0.15	0.11	0.31	0.24	0.22
Pe FGG	0.22	0.14	0.21	0.18	0.27	0.22	0.18	0.29
DS FGG	0.06	0.12	0.17	0.15	0.03	0.06	0.10	0.10
Cen FGG	0.48	0.49	0.42	0.40	0.43	0.40	0.25	0.33
CA ER	0.32	0.34	0.31	0.31	0.35	0.55	0.29	0.45
Pe ER	0.23	0.16	0.29	0.25	0.26	0.21	0.14	0.24
DS ER	0.15	0.14	0.56	0.39	0.15	0.16	0.24	0.24
Cen ER	0.27	0.24	0.24	0.26	0.27	0.26	0.24	0.23
Even ER	0.24	0.20	0.29	0.29	0.27	0.22	0.22	0.22
CA GGP	0.30	0.31	0.32	0.31	0.38	0.54	0.27	0.40
Pe GGP	0.21	0.14	0.28	0.21	0.26	0.20	0.12	0.19
DS GGP	0.14	0.14	0.56	0.36	0.17	0.13	0.20	0.21
Cen GGP	0.29	0.24	0.26	0.26	0.37	0.24	0.21	0.20
Overall GGP	0.25	0.20	0.31	0.28	0.33	0.25	0.21	0.21

generated in the range of 20–25% of their goals from this tactic. Centre play seemed to be the most consistent goal generator, at least for the top six teams who all generating between 40 and 48% of their goals from this tactic. In fact, offensive ERs for centre were surprisingly uniform amongst all eight teams. EER also exhibited little variability. Hungary and Serbia had the highest overall offensive GGP, consistent with the fact that these two teams are often considered dominant offensive teams. Serbia was particularly effective with direct shots, generating a goal on more than one out of every two uses of this tactic.

Looking at defensive statistics, it is clear that both Croatia and Italy won most of their games on this side of the pool. Croatia's overall defensive GGP was lower than any other team by 0.04 meaning they gave up, on average, four fewer goals out of every 100 plays. Croatia was especially effective in stopping power-play situations and outside shooting tactics. Their one weakness seemed to be against counterattacks: one out of every four goals scored against them came from use of this tactic and their defensive counterattack ER was the highest amongst all eight teams. Italy also performed

Table 10 Defensive team comparisons.

Defense	CRO	ITA	SRB	MNE	HUN	ESP	AUS	USA
Plays per Game	38.75	36.75	38	36.5	38	39.5	36.25	36.75
Exclusions	9.75	10.75	11.00	12.25	10.25	9.50	12.00	9.75
ECR	0.31	0.35	0.55	0.47	0.61	0.39	0.56	0.48
Quick	1.25	1	2	1.75	1.5	1	1.25	0.5
CA FGG	0.25	0.15	0.17	0.11	0.15	0.20	0.21	0.22
Pe FGG	0.18	0.31	0.23	0.31	0.17	0.24	0.13	0.24
DS FGG	0.05	0.08	0.11	0.08	0.17	0.08	0.08	0.07
Cen FGG	0.36	0.35	0.30	0.43	0.45	0.44	0.54	0.44
CA ER	0.39	0.29	0.29	0.26	0.37	0.36	0.35	0.34
Pe ER	0.13	0.25	0.20	0.32	0.21	0.23	0.19	0.19
DS ER	0.09	0.20	0.26	0.20	0.51	0.19	0.17	0.37
Cen ER	0.24	0.24	0.25	0.25	0.25	0.30	0.26	0.26
Even ER	0.19	0.24	0.23	0.27	0.26	0.25	0.23	0.24
CA GGP	0.32	0.23	0.32	0.26	0.41	0.31	0.37	0.33
Pe GGP	0.10	0.23	0.17	0.29	0.17	0.20	0.18	0.18
DS GGP	0.05	0.13	0.27	0.18	0.55	0.16	0.18	0.31
Cen GGP	0.18	0.18	0.27	0.25	0.30	0.27	0.30	0.27
Overall GGP	0.16	0.20	0.24	0.25	0.29	0.23	0.27	0.25

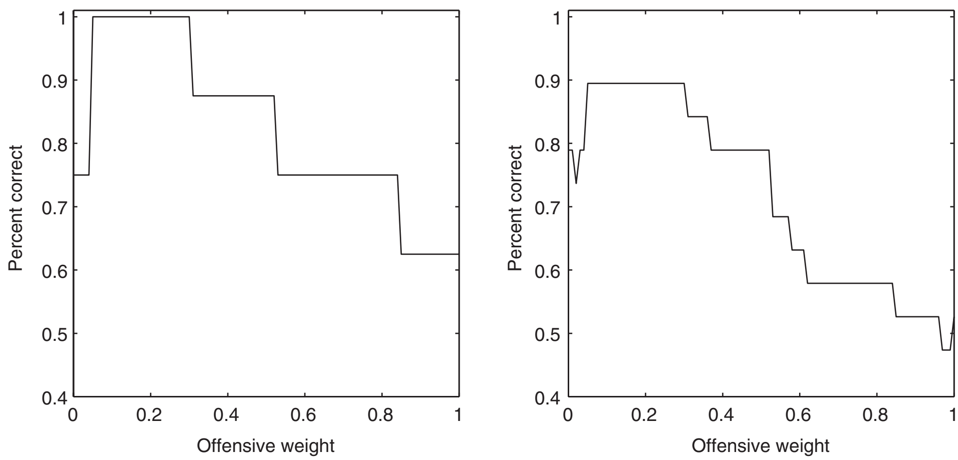

Figure 2 Percent of games correctly predicted by the GGP model with different offensive weights (α) in the playoffs (left) and in all 19 non-tied games (right) between the eight teams leading up to the championship.

well on the defensive end with the second lowest ECR and overall GGP.

Notice that there was no single statistic on offense or defense which could be ordered in such a way to perfectly predict the outcome of the playoffs. This makes sense since conventional wisdom would say that some combination of offense and defense is important. We present two models for predicting the playoffs which combine information from both aspects of game play. In Model 1 (the GGP Model), we simulate a contest between teams *i* and *j* in the following manner: Team *i* receives n_{ij}^{α} plays each of which results in a goal with probability p_{ij}^{α} where

$$n_{ij}^{\alpha}=\alpha PO_i+(1-\alpha)PD_j$$
$$p_{ij}^{\alpha}=\alpha GGPO_i+(1-\alpha)GGPD_j$$

for some α between 0 and 1 with

PO_i=Average numbers of offensive plays per game for team *i*
PD_j=Average numbers of defensive plays per game for team *j*
$GGPO_i$=Offensive GGP for team *i*
$GGPD_j$=Defensive GGP for team *j*

In other words, we model the number of goals team *i* scores against *j* by a Binomial random variable with the number of trials and success rate equal to some convex combination of team *i*'s offensive and team *j*'s defensive rates[7]. Similarly, we model the number of goals scored by *j* against *i* as an independent Binomial random variable with parameters n_{ji}^{α} and p_{ji}^{α}.

We then sought an offensive weight α which optimized our prediction probabilities for the eight games in the final playoffs. The results are illustrated in Figure 2. Clearly, the qualitative shapes of both graphs lean towards lower offensive weights (α<0.5). From our previous observations on team statistics, this conclusion is logical given that the gold and silver winners were also the top defensive teams. With an offensive weight α in the range of 0.19–0.30, the GGP model correctly predicted all eight playoff games and 9 of the 11 (non-tied) pre-playoff games as well.[8]

An advantage of using a probabilistic model is that in addition to estimating the number of goals scored by each team (see Table 11), we were able to estimate odds: if we let X_{ij}^{α} be the random variable denoting the number of goals scored by team *i* against team *j* with weight α, then using the independence assumption from our model, we have

$$P_{ij}^{\alpha}=P(i\text{ beats }j)=P(X_{ij}^{\alpha}>X_{ji}^{\alpha})=\sum_{\ell<k}P(X_{ij}^{\alpha}=k)P(X_{ji}^{\alpha}=\ell).$$

Table 11 Mean goals matrix for the GGP Model with α=0.3.

	AUS	CRO	ESP	HUN	ITA	MNE	SRB	USA
AUS	*	6.93	8.75	10.21	7.72	8.84	8.89	9.01
CRO	9.82	*	9.19	10.65	7.94	9.26	9.32	9.19
ESP	9.90	7.27	*	10.73	8.02	9.34	9.41	9.28
HUN	10.45	8.13	9.90	*	8.62	9.90	9.99	9.84
ITA	9.34	6.87	8.69	10.15	*	8.78	8.83	8.71
MNE	10.15	7.53	9.55	10.99	8.27	*	9.66	9.53
SRB	10.46	8.05	9.87	11.31	8.81	9.90	*	10.10
USA	9.12	6.74	8.73	10.20	7.50	8.82	8.87	*

The entry in row *i* column *j* is the expected number of goals scored by team *i* vs team *j* under the GGP model.

7 Note that we round n_{ij}^{α} to the nearest integer.

8 The two exceptions being USA vs Hungary and USA vs Montenegro.

Table 12 Probability matrix for the GGP Model with α=0.3.

	AUS	CRO	ESP	HUN	ITA	MNE	SRB	USA
AUS	*	0.17	0.33	0.42	0.28	0.31	0.29	0.43
CRO	0.75	*	0.65	0.71	0.57	0.63	0.58	0.71
ESP	0.57	0.25	*	0.53	0.37	0.43	0.40	0.51
HUN	0.47	0.21	0.37	*	0.29	0.34	0.32	0.41
ITA	0.62	0.32	0.52	0.61	*	0.50	0.45	0.58
MNE	0.59	0.27	0.47	0.56	0.39	*	0.42	0.52
SRB	0.61	0.31	0.50	0.58	0.44	0.47	*	0.58
USA	0.46	0.20	0.39	0.48	0.31	0.37	0.32	*

The entry P_{ij} in row *i* column *j* is the probability that team *i* will beat team *j*. Note that $P_{ij}+P_{ji}<1$ in each matchup because there are non-trivial chances of ties.

The probabilities on the right can then be calculating from standard formulas for the Binomial mass function (see, for example, Ch. 2 in Durrett 2009).[9] Table 12 shows that the probabilities P_{ij}^{α} for the case where α=0.3. If one looks at the two incorrectly predicted games at this weight, we can see that the USA vs Hungary matchup had nearly even odds (0.48/0.41≈1.17 to 1 in favor of the USA) while the USA vs Montenegro was more of an outlier (predicted odds of 1.4–1 in favor of Montenegro). However, it should also be noted that this game occurred early in the tournament and USA won their first three matches before losing the rest. Notice also that the playoff game between Serbia and Italy had almost even odds and it was this game which our model first started incorrectly predicting once α>0.3. Croatia was, as expected, heavily favored over all other teams.

Model 2 (the Exclusion Model) was defined in the same way as the GGP model except that we replaced number of plays with number of exclusions and GGP with ECR. The predictions of the Exclusion model are included in Figure 3. In the range of offensive weights 0.26–0.39, the Exclusion Model predicted seven of eight playoff games, the incorrect prediction occurring in the quarterfinal match between Montenegro and Spain. With α=0.31, the model correctly predicted 9 of 11 pre-playoff games as well.[10] A second prediction plateau occurred in the range of offensive weights 0.58–0.66. On this plateau, the model gave an incorrect prediction in Serbia vs Italy.[11] Note that the remaining six of eight playoff games were correctly predicted for all weights between 0 and 0.8, suggesting that in the Exclusion Model, the weight may be relatively unimportant in most games.

To further assess the value of our models, we turned to data from the 2013 FINA World Championships where the men's gold medal was taken by Hungary, a strong offensive team. We did not have the same detailed game logs allowing us to compute number of plays in these games so we further simplified our GGP model by assuming that each team received an even number of plays per game and ran our GGP model with goals scored for and against each team in the opening rounds. Interestingly, we obtained a similar range of offensive weights ($0.2 \leq \alpha \leq 0.4$) which optimized our correct prediction probability, yielding correct predictions in 12 of 16 games. It is also worth noting that three of the four mispredicted games involved Hungary and two of these three games were decided by a one goal margin. Turning to our ECR model, however, a different pattern began to emerge. Using an offensive weight of α=0.9, we obtained an optimal number of correct predictions in 14 of the 16 games and the overall trend clearly favored offense.

Conclusions

We have introduced a new statistic, Efficiency Rating (ER), which measures the efficiency of an offensive tactic in water polo by taking a weighted average of direct and indirect goals generated as a consequence of employing the tactic. Using this measure, we found that counterattacks were, on average, more effective than any even strategy and that direct shot was the most efficient even strategy despite being used far less frequently than perimeter or centre. This latter observation leads to the interesting conjecture that teams may be able to increase offensive efficiency by increasing direct shot tactical choices. We also found that ER for counterattacks and perimeter favored the winning team in a significant proportion of unbalanced, but not close games while ER for Centre did not exhibit a significant effect size in either type of contest. In contrast, Exclusion Conversion Rate correctly classified the outcome in about 90% of both close and unbalanced games, suggesting that the ability to convert power-play opportunities may be the most significant factor in determining the outcome of elite men's water polo contests. We also highlighted the importance of tracking goals scored in the transition period between the end of an exclusion and the return to even play in addition to goals scored during the 20 s of the exclusion. Using a model based on our new

9 In fact, one can compute the probability that team *i* beats *j* by *k* goals for any $k \geq 0$ in a similar manner.

10 Incorrect: Serbia vs Hungary and Montenegro vs Hungary. With α=0.03, we also incorrectly predicted Hungary vs USA so it appears that the Exclusion Model with low offensive weight does especially poorly in predicting matches involving Hungary.

11 … and USA vs Montenegro in the preliminary round.

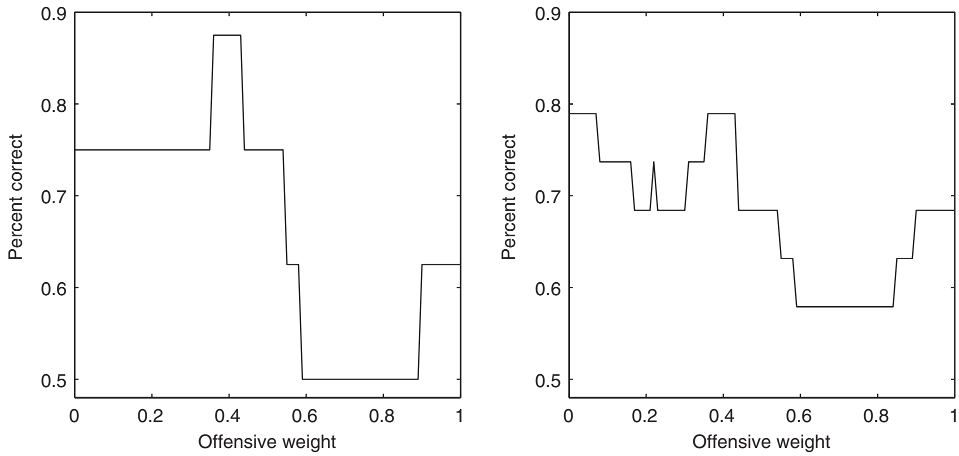

Figure 3 Percent of games correctly predicted by the Exclusion model with different offensive weights (α) in the playoffs (left) and in all 19 non-tied games (right) between the eight teams leading up to the championship.

summative statistic Goals Generated per Play (GGP), we were able to successfully predict all eight playoff games from the 2012 Olympic Men's Water Polo from preliminary round performance. Our model suggested that defense weighed more heavily than offense on the path to the 2012 gold, however, further validation is needed to determine if this result is characteristic of elite men's water polo in general or an artifact of individual team strengths in the 2012 games. One limitation of our study was that we focused on the analysis of offensive tactics. In the future, we would like to develop and analyze measures of tactical efficiency for defensive tactics (e.g., zone, press, and split) as well and assess the impact of such choices on game outcomes.

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Appendix

Description of Tactics

9. *Direct Shot* – An attempt by any player to get fouled outside the 5 m line to get a free throw and shoot directly to the goal. Only free throws which result from deliberate attempts to get fouled are tracked as direct shots which distinguishes this tactic from free throw statistics considered in other papers; see Lupo et al. (2010), 2011, 2012b, 2014).
10. *Centre Forward* – The centre forward is the player closest to the goal who occupies the central game area at about 2 m from the opposing goal (Lozovina et al. 2004; Lupo et al. 2012b). Any action that occurs at the centre position is logged as a centre forward tactic.
11. *Perimeter Players* – Any non-free throw shot, or attempted shot, that occurs at one of the non-centre forward positions is logged as a perimeter tactic.
12. *Drive* – A tactic performed by swimming toward the goal to get a pass (generally close to the goal to effectively shot), or a favorable game situation for a team mate (influencing the opponents defensive arrangement). This tactic may also be referred to as a cut.
13. *Post up* – A tactic exclusively executed by perimeter players and differentiated from a drive by the attempt to turn ones' back to the defender in order to get an opponents exclusion.
14. *Pick* – Two players "cut" in an attempt to get an offensive advantage with respect to the defenders (similar to a screen in basketball).
15. *New Centre* – Similar to a post up with the added facet that the centre vacates the region in front of the goal and the perimeter player that comes in stays as a replacement.
16. *Double Centre Forward* – Similar to a post up, but distinguished by an extended period of time in which a player continues to work for position as opposed to looking for an opportunistic advantage. The offense

often shifts and balances into a formation similar to that in the 4–2 MA (see below).

17. *Counterattack* – Any game situation where, the number of offensive players is larger than that of the defense relative to the ball position, determining a numerical advantage for the offensive players. This state persists until the numerical superiority is neutralized by the defense; see also Lupo et al. (2010), 2011, 2012a, 2014).
18. *4–2 PP* – An offensive team arrangement during a power-play: two centre forwards at 2-m in front of the posts of the opponent goal, and four perimeter players round the two centre forwards; see also Lupo et al. (2012a), 2014).
19. *3–3 PP* – An offensive team arrangement during a power-play: one centre forward centrally located at 2-m from the opponent goal, and five perimeter players round the centre forward.
20. *Quick* – Any game action that occurs at the start of a power-play, before a definite offensive (i.e., 4–2 PP, 3–3 PP) or defensive arrangement.

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