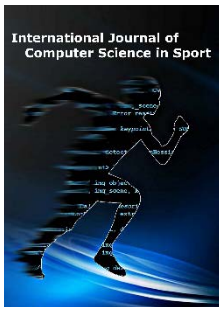
International Journal of Computer Science in Sport

DE GRUYTER OPEN

Volume 15, Issue 1, 2016

Journal homepage: http://iacss.org/index.php?id=30

DOI: 10.1515/ijcss-2016-0003



Predictive models of the 2015 Rugby World Cup: accuracy and application

O'Donoghue, P., Ball, D., Eustace, J., McFarlan, B. Nisotaki, M.

Cardiff School of Sport, Cardiff Metropolitan University, Cyncoed Campus, Cardiff, Wales, CF23 6XD, UK.

Abstract

The current investigation compared 12 models of outcomes of international rugby union matches and then used the most accurate model to investigate performances within the 2015 Rugby World Cup. The underlying linear regression models were used within a simulation package that introduced random variability about performance evidenced by the residual distribution of the regression analyses. Each model was used within 10,000 simulations of the 2015 Rugby World Cup from which match outcome and team progression statistics were recorded. The most accurate model with respect to the actual 2015 tournament was developed using data from all seven previous tournaments rather than restricting cases to the most recent three tournaments. The model was more accurate when the data used violated the assumptions of linear regression rather than transforming variables to satisfy the assumptions. The model included World ranking points as a predictor variable and was more accurate than corresponding models that represented relative home advantage as well. The most accurate model used separate models for the pool and knockout stage matches although the 9 models that separating these match types were less accurate on average than when the two match types were considered together. This model was used to investigate properties of the 2015 Rugby World Cup. The tournament disadvantaged three teams in the World's top 5 who were drawn in the same pool. Teams ranked in the World's top 7 did not perform as well as predicted while teams ranked 16th and below performed better than predicted suggesting that the strength in depth in international rugby union is increasing. There was a small effect of having additional recovery days from the previous match compared to the opponents which was worth 4.1 points. The information produced by this research should be considered by those design tournaments such as the Rugby World Cup.

KEY WORDS: VENUE EFFECTS, RECOVERY, REGRESSION, SIMULATION.

Introduction

Predictive modelling is utilised within many areas including business, economics, politics, geology and medicine. Forecasting match outcomes in sports has been a challenging test of modelling techniques and variables due to the unpredictable nature of sport (Condo et al., 1999). Forecasting match outcomes in sport is inherently difficult which is why betting agencies are prepared to accept bets on sports events (Stefani, 1998; Herzog & Hertwig, 2011). Within sport, predictive modelling can be applied to tournament design (O'Donoghue, 2005a) and the understanding of injury rates and rehabilitation (Kiesel et al., 2014; Sainani, 2014). There are a variety of modelling techniques including statistical models, simulation systems and artificial neural networks (O'Donoghue et al., 2004). Given the important application areas where predictive models are applied, it is important to strive for improvement in the accuracy of modelling techniques. Therefore, studying the use of different variables within models as well as the modelling techniques themselves provides valuable insights into strengths and limitations of alternative approaches. The current investigation aims to compare the accuracy of alternative models of international rugby union matches and then apply the most accurate model to evaluate tournament design and factors influencing performance. The 2015 Rugby World Cup is used as an example within the paper. The paper commences by introducing factors to be included within the models followed by descriptions of the data sources, modelling techniques and evaluation process used to compare the models. The most accurate model can then be used to predict performances of teams and compare these to the actual performances within the tournament. Differences to predicted performances are used to evaluate the strength in depth of international rugby teams, the fairness of the tournament structure and the effect of differing recovery days from previous matches experienced by teams within matches.

The quality of opposition is recognised as the strongest source of variability in sports performance (McGarry and Franks, 2004). At international level in team games, World ranking points reflect team quality (McHale and Davies, 2007) and has consistently been found to be the strongest predictor of match results in rugby (O'Donoghue and Williams, 2004; O'Donoghue, 2009; O'Donoghue, 2012a) and soccer tournaments (O'Donoghue et al., 2004; O'Donoghue, 2005b, 2006, 2010, 2014). For the purpose of this paper, the term "relative quality" is used to represent the difference in World ranking points between two teams contesting a match.

A further factor that has been used in predictive models is "relative home advantage". There is typically a single host nation for an international tournament. However some teams will travel further than others and this may impact on the chance of winning. Thus rather than classifying teams as home or away within such tournaments, relative home advantage is the difference in how far two teams have had to travel to participate in the tournament. In soccer, the majority of World Cup tournaments have been won by teams from the same continent as the host nation. Home advantage does not appear to be as strong in international rugby union with four of the seven rugby World Cups between 1987 and 2011 being won by teams from different continents to the host nation. There is a wealth of research evidence supporting the concept of home advantage in sport (Courneya and Carron, 1992; Pollard and Pollard, 2005; Pollard and Gómez, 2009; Gómez et al., 2013). Rugby Union has a reputation of being a 'friendlier' sport than soccer. Therefore, some factors such as crowd size and travel distance, mentioned in Gómez et al.'s (2013) review, may not be as important in rugby as they are in soccer. Nonetheless, venue effects in Rugby Union have been neglected by previous research and so there is a need to assess the impact of relative home advantage in the sport.

Predictive models of match outcomes have tried to represent relative home advantage on a continuous scale to reflect distance travelled to tournaments (O'Donoghue, 2012a). Typically, the distance between a country's capital city and the capital city of the country hosting the tournament is used to crudely reflect travel distances (O'Donoghue et al., 2004). This does not take into account travel routes taken, airport transfers or that players may be based in other countries for domestic competition. Assuming that relative home advadvantage effects are linearly related to distance travelled to tournments has resulted in predictions being biased towards home nations in previous research. For example, O'Donoghue et al.'s (2004) linear regression model used to predict the 2002 FIFA World Cup predicted that Japan would defeat South Korea in the final. The matches of World Cups prior to 2002 used to produce the model did not involve many teams travelling the ranges of distances that European and South American teams needed to travel to Japan and South Korea. Goal difference between teams teams was found to increase as relative home advantage increased. However, the rate of increase in goal difference reduced as relative home advantage increased. Therefore, square root and logarithmic transformations of distance travelled variables were produced. The alternative models that used these transformed variables predicted that France would defeat Germany in the final. While this model did not correctly predict that Brazil would win the 2002 tournament, it was more accurate than assuming a linear relationship between distance travelled and match results. It, therefore, appears that the effect of travel does not increase linearly and that home advantage increases by smaller amounts as away teams travel from longer distances. Given the crude measurement of distance travelled, it is difficult to justify the use of giant circle distance between capital cities and a categorical version of the variable may be more effective.

A limitation of the regression based models used in previous research in rugby union is that the same model is used for pool stage matches and knockout stage matches (O'Donoghue, 2009, 2012a). Pool and knockout matches differ in two key ways. Firstly, teams may lose a pool match without being eliminated from the tournament. Secondly, there is a possibility that pool matches will be drawn. During the knockout stages there is a winner and a loser of each match even if extra time and penalty kicks are required. The difference in these two types of matches has been recognised in some predictive models using different modelling techniques for the two types of match. For example, discriminant function analysis has been used to predict whether pool stage matches are wins, draws or losses while binary logistic regression has been used to force a win or a loss to be predicted for knockout stage matches (O'Donoghue et al., 2004, 2005b, 2006). In the Rugby World Cup, the knockout stage matches are typically closer than matches in the pool stage because weaker teams have been eliminated during the pool stages. Research into basketball suggests that round robin and knockout games should be approached differently. Sampaio and Janeira (2003) found that regular season game results depend on different performance variables than play-off games in the Portuguese Basketball league. More recently, Garcia et al. (2013) found further differences between regular season and play-off games in the Spanish Basketball league. Therefore, it would be interesting to compare the accuracy of predictive models where pool stage matches and knockout stage matches were considered together and separately.

There is a trade-off between the volume of data and the currency of the data used to produce predictive models. Recent predictive models of soccer have been produced from data from tournaments including and since the 2006 FIFA World Cup (O'Donoghue, 2010, 2014). The reason for this was that the FIFA World ranking system changed just before the 2006 FIFA World Cup. World ranking points are considered to be a valid way of representing team quality in rugby, soccer and cricket (McHale and Davies, 2007). The data used to predict sports performances needs to be reasonably current due to changes in the nature of sports as well as rule changes that are made. There was no rugby World ranking point system in place during the 1987 to 1999 Rugby World Cups (O'Donoghue and Williams, 2004). This has meant that previous studies of rugby union performance have used combinations of real and synthetic world rankings to produce predictive models. There is now sufficient data from the 2003, 2007 and 2011 Rugby World Cups to produce predictive models using real world rankings that are also more current than data from previous tournaments. A further issue with data used from early rugby World Cup tournaments is that some matches were played while 4 points were awarded for a try rather than 5 points. While the results of these matches were adjusted within data sets used to make tries worth 5 points, there is an issue of how teams would have played if 5 points had actually been awarded for a try. For example, one drawn match between France and Scotland in the 1987 tournament would have been won by France if there were 5 points awarded for tries rather than 4. This would certainly have an impact on the way the teams played towards the end of the match. Given the choice between basing models on a smaller number of recent matches or a larger number of matches including dated matches, it would be interesting to see which of these alternatives produces the most accurate model of rugby match outcomes.

Simulation models used in recent research in rugby union (O'Donoghue and Williams, 2004; O'Donoghue, 2009; O'Donoghue, 2012a) and soccer (O'Donoghue et al., 2004; O'Donoghue, 2005b, 2006, 2010, 2014) are based on linear regression. Linear regression has assumptions that should be satisfied by the data used to create predictive models (Ntoumanis, 2001, 120-1; Tabachnick & Fidell, 2001). Firstly, relationships between independent variables and the dependent variable should be linear (Newell *et al*., 2010: 140; Kleinbaum et al., 2013). The independent variables, dependent variables and residual values should be free of outliers and extreme values (Tabachnick and Fidell, 2007: 124). Furthermore, there should be no outliers within the multivariate space (Ntoumanis, 2001: 124-5). There should be at least 20 matches for every independent variable present (Ntoumanis, 2001: 120-1) and independent variables should not be highly correlated (Allison, 1999: 137-8). The residuals should be normally distributed (Vincent, 1999: 111), homoscedastic (Anderson *et al*., 1994: 521, Vincent, 1999: 111) and independent (O'Donoghue, 2012b, p. 161). A series of studies of predictive models of international soccer and rugby matches has produced conflicting evidence about the accuracy of models where these assumptions have been satisfied (O'Donoghue, 2005b, 2006, 2010, 2012a, 2014). The difference in accuracy of models where assumptions have been violated and corresponding models where the assumptions have been satisfied has been similar. A majority of the studies revealed that the models where data violated the assumptions of linear regression were more accurate with respect to the actual results of matches than the models where the assumptions were satisfied. Given the conflicting evidence about the effectiveness of satisfying the assumptions of linear regression, the current investigation will add to the debate by deliberately comparing models of rugby union performance where data have violated and satisfied the assumptions.

The intention of the current investigation was to compare the accuracy of 16 predictive models of the 2015 Rugby World Cup with respect to the match results in the actual tournament. It was hoped to compare 16 models combining four model types within a 2 x 2 x 2 x 2 design. The first factor was whether the assumptions of the predictive modelling technique were **satisfied** or **violated** by the data used to create the models. The second factor was whether data from **all** of the previous Rugby World Cups were used (1987-2011) or only **recent** data were used (2003-2011). Thirdly, the models were classified by whether pool and knockout stage matches were considered **separately** or **together**. Finally, there were models that represented relative home advantage (**yes**) and others that didn't (**no**). Unfortunately, there were 4 models where the authors were unable to transform the data to satisfy the assumptions of linear regression. Therefore, 12 models were compared.

Methods

Variables

The current investigation considered each match to be played between a higher and a lower ranked team according to IRB (International Rugby Board) World Rankings. The variables were expressed with respect to the higher ranked team within the match.

- The dependent variable, PD (points difference) is the difference between the higher and lower ranked teams' points scored in the match. If this value is zero then the match was a draw, if it is positive then the higher ranked team won the match and if it is negative then the lower ranked team won the match.
- The first independent variable, R_{diff} (relative quality) is the difference between the higher ranked team's world ranking points (R_H) and the lower ranked team's world ranking points (R_L). The source of the World ranking points was the World Rugby website (http://www.worldrugby.org/rankings accessed 31/3/15 to 15/9/15).
- A second independent variable, D_{diff} (relative home advantage) was used in some of the models. This was defined as the difference between the giant circle distance between the capital city of the higher ranked country and the capital city of the host nation of the match (D_H) and the same distance for the lower ranked nation (D_L) (www.indo.com/distance accessed 31/3/15). Thus a negative value means that the higher ranked team has more of a home advantage because they travelled a shorter distance to the tournament.

Modelling

Two sets of data from previous Rugby World Cup tournaments were loaded into SPSS (SPSS; an IBM company, Amarouk, NY). There were 280 matches in the data set for **all** previous tournaments and 143 matches in the data set for **recent** tournaments. Linear regression was used to produce models of PD in terms of R_{diff} and D_{diff}. PD increased as R_{diff} increased. However, the rate of increase of PD got smaller as R_{diff} increased. Therefore, various logarithmic and root transformations were applied to the ranking and relative home advantage variables in exploratory attempts to satisfy the assumptions of linear regression. The difference between the logarithmically transformed rankings of the teams within matches, $L_{diff} = \ln(R_H) - \ln(R_L)$, was successful in satisfying the assumptions when **recent** matches were analysed. Similarly, the difference between the square roots of the distances travelled by teams within matches, $S_{diff} = \sqrt{D_H} - \sqrt{D_L}$, was successful in satisfying the modelling assumptions when **recent** matches were used.

The data sets were logically split in some analyses so that pool and knockout stage matches could be analysed **separately** while other analyses kept all of the matches **together**. A total of 16 regression analyses were done in SPSS saving residual and predicted values so that the data could be tested with respect to the assumptions of linear regression. The independent variables and residual values for PD were explored to test whether they were normally distributed, free of outliers and extreme values. Correlation techniques were used to assess associations between independent variables as well as between predicted and residual values for PD. One way ANOVA tests were used to compare residual values for PD between different tournaments to ensure they were independent.

The intention of the analysis was to use 16 (2 x 2 x 2 x 2) models for PD. The first factor was whether the assumptions of the predictive modelling technique were **satisfied** or **violated** by the data. The second factor was whether data from **all** (1987-2011) or only **recent** Rugby World Cup tournaments (2003-2011) were used. Thirdly, the models were classified by whether pool and knockout stage matches were considered **separately** or **together**. Finally, there were models that represented relative home advantage (**yes**) and others that didn't (**no**). The 8 models where variables were untransformed and the data violated the assumptions of linear regression were created. However, the authors could not transform variables for the 4 models that used the **all** previous matches in a way that the data satisfied all of the assumptions. In particular, it was not possible to transform the variables in a way that produced residual values for PD that were normally distributed. The remaining 4 models (based on **recent** data only) satisfied the assumptions of linear regression when L_{diff} and S_{diff} were used instead of R_{diff} and D_{diff} respectively. Therefore, 12 predictive models were compared within the current investigation instead of the intended 16 models.

Satisfying the assumptions of linear regression

Inspection of scatter charts indicated that the L_{diff} and S_{diff} variables had more of linear relationship with PD than the untransformed R_{diff} and D_{diff} variables. There were no outliers in the L_{diff} or S_{diff} variables. Kolmogorov Smirnov tests revealed that the residual values for PD were normally distributed for all 4 models based on **recent** data ($p > 0.05$). However, there were three outliers in the residual values for all 4 of these models. These were a match where Australia beat Namibia by 142 points, a match where Ireland beat Namibia by 15 points and a match where Wales beat Fiji by 66 points. These matches were real matches and the outliers did not result from measurement error. Matches like these could occur within the 2015 tournament being predicted. It was, therefore, decided not to remove these three outliers from the data used to create the models. As well as being normally distributed, the residual values for PD were homoscedastic and independent. Homoscedasticity was shown by absolute correlations between predicted and residual values for PD being 0.252 or lower. A one-way ANOVA revealed that neither residual values nor the absolute residual values for PD were influenced by year of tournament ($p \geq 0.464$). There were no high correlations between the independent variables used in any of the 4 models ($|r| \leq 0.220$). Finally, the number of matches used satisfied the requirement for at least 20 matches per independent variable. There were 119 pool and 24 knockout stage matches in the **recent** data set with one or two independent variables being included in any of the 4 models.

The models are identified by a four letter code that indicates the status of the four factors of interest within the models:

V – the data used violates the assumptions of linear regression.

S – the data used satisfy the assumptions of linear regression.

A – data from all previous Rugby World Cups used to produce the model.

R – data from recent (2003-2011) Rugby World Cups used to produce the models.

T – pool and knockout stage matches modelled together.

S – pool and knockout stage matches modelled separately.

N – relative home advantage not included.

Y – relative home advantage included as a numerical variable.

Table 1 shows the regression coefficients and standard deviations of residual values for PD for the 12 models compared within the current investigation.

Table 1. The predictive models for points difference (PD) and standard deviation of residual values for PD.

Model	Assumptions	Data Set	Match Types	Relative Home Advantage	Model for PD	SD res
1 VATN	Violated	All	Together	No	$-0.697 + 2.395\ R_{diff}$	19.236
2 VATY				Yes	$-0.735 + 2.400\ R_{diff} + 0.0000803\ D_{diff}$	19.229
3 VASN			Separately	No	Pool: $1.538 + 2.364\ R_{diff}$ KO: $1.008 + 1.174\ R_{diff}$	20.070 12.679
4 VASY				Yes	Pool: $1.401 + 2.373\ R_{diff} + 0.000183\ D_{diff}$ KO: $1.167 + 1.124\ R_{diff} – 0.000313\ D_{diff}$	20.034 12.431
5 VRTN		Recent	Together	No	$-4.721 + 2.781\ R_{diff}$	18.532
6 VRTY				Yes	$-4.828 + 2.796\ R_{diff} + 0.000190\ D_{diff}$	18.482
7 VRSN			Separately	No	Pool: $-2.556 + 2.742\ R_{diff}$ KO: $-1.041 + 1.046\ R_{diff}$	18.843 12.508
8 VRSY				Yes	Pool: $-2.743 + 2.758\ R_{diff} + 0.000174\ D_{diff}$ KO: $-0.928 + 0.986\ R_{diff} – 0.000182\ D_{diff}$	18.803 12.432
9 SRTN	Satisfied	Recent	Together	No	$-4.526 + 211.122\ L_{diff}$	18.471
10 SRTY				Yes	$-4.528 + 211.899\ L_{diff} + 0.013\ S_{diff}$	18.519
11 SRSN			Separately	No	Pool: $-2.656 + 207.672\ L_{diff}$ KO: $-0.688 + 84.393\ L_{diff}$	19.003 12.545
12 SRSY				Yes	Pool: $-2.745 + 208.649\ L_{diff} + 0.014\ S_{diff}$ KO: $-0.301 + 72.347\ L_{diff} - 0.026\ S_{diff}$	18.990 12.632

Simulation

A simulation package was developed in Matlab version 7.0.1 (Mathworks Inc., Natick, MA) to simulate the 2015 Rugby World Cup 10,000 times, accumulating progression statistics for each team. The simulator was configured and run 18 times using each of the underlying regression models shown in Table 1. The standard deviation of the residuals for PD was used to include random variability within the simulations. The simulator was initialised with information about the teams' World ranking points as well as distances from each country's capital city to London and Cardiff; some matches were played in Wales. The simulation of a match worked by determining the predicted value for PD using the given regression model. A random number between 0 and 1 was then generated and used to look up a normal distribution curve with a mean value equal to the predicted PD and a standard deviation being the standard deviation for the residual values from the data used to create the model. The random number dictated the area of the normal distribution curve to the left of the simulated PD value. In pool matches, simulated PD values greater than 0.5 were rounded up to indicate a win for the higher ranked team, values less than -0.5 were rounded down to indicate a win for the lower ranked team, with values of between -0.5 and 0.5 being counted as draws. In knockout matches, one team has to be eliminated even if extra time and / or penalty kicks are required. Therefore, PD values of greater than or equal to 0 were used to represent a win for the higher ranked team in the match and values of less than 0 were counted as wins for the lower ranked team. Figure 1 shows an example of a normal distribution curve for the pool match between England and Wales using the first model (VATN). England and Wales had 85.04 and 84.63 World ranking points respectively and when this differences was used by the VATN model (-0.697 + 2.395 R_{diff}) the predicted result was England scoring 0.285 points more than Wales. However, with the standard deviation of the PD residual values being 19.236, the normal distribution curve in Figure 1 had an area of 0.493 for PD values greater than 0.5 indicating an England win and an area of 0.475 for PD values less than -0.5 indicating a Wales win. This left an area of 0.032 between PD values of -0.5 and 0.5 representing the chance of a draw.

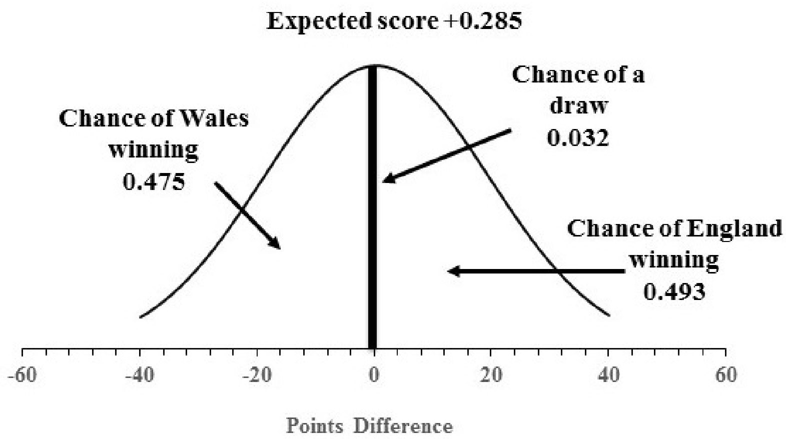


Figure 1. Distribution of points difference implemented by the simulator for the England v Wales pool match.

The percentage of the 10,000 simulations of each pool match that were predicted to be wins, draws and losses for the higher ranked team were recorded by the simulator. The progression statistics accumulated for each team included the percentage of simulated World Cups where they finished first or second in their pool, won a quarter-final, semi-final, third place play-off and the final.

Evaluation Scheme

The 2015 Rugby World Cup consisted of 40 pool matches and 8 knockout matches. The evaluation method awarded a maximum of 1 mark for each match. The fraction of a mark awarded depends on the proportion of simulated Rugby World Cups where a given model predicted the correct result. For example, consider the opening match between England and Fiji which the first of the 12 models (VATN) predicted to be a win for England in 87.2% of simulated tournaments, a win for Fiji in 11.7% of simulated tournaments and a draw in 1.0% of simulated tournaments. England won this match and so this predictive model was awarded 0.872 points for the match.

No marks were allocated for correctly identifying quarter-finalists. This decision was taken to avoid the pool match predictions essentially being evaluated twice. For the knockout stages, a mark was allocated for each of the 4 semi-final places, the 2 final places, the third placed team and the tournament winner. The first predictive model (VATN) had New Zealand reaching the semi-finals in 90.6% of simulated tournaments, the final in 74.3% of simulated tournaments and winning 62.3% of the simulated tournaments. Therefore, because New Zealand won the actual 2015 Rugby World Cup, this predictive model was awarded 0.906 + 0.743 + 0.623 = 2.272 marks for predicting New Zealand's performances in the knock out stages. Altogether, the maximum possible mark for a prediction was 48 but realistically this is unachievable because it would require 100% of simulated tournaments to correctly predict the actual results of all 48 matches of the tournament. The significance of each of the 4 factors was also evaluated using independent samples t-tests.

Results

Table 2 shows the accuracy with which the models predicted the pool matches while Table 3 shows the accuracy with which the knockout stages were predicted. The accuracy of the models was similar with prediction points ranging from 30.90 to 31.75 out of 40 points available for pool matches (meaning 77.25% to 79.38% correctness for pool stage matches). The accuracy of knockout stages predictions was not as high due to inaccurate predictions of some pool stage matches propagating errors into the knockout stages. The prediction points for the knockout stages ranged from 2.93 to 4.29 out of 8 (meaning 36.63% to 53.63% correctness for predicting teams reaching the various knockout stages). Figure 2 shows the overall accuracy of the models scored out of 48 points. The models that violated the assumptions of linear regression were significantly more accurate than those that satisfied them ($p = 0.044$). Models created using data from all previous Rugby World Cups were significantly more accurate than those created using only the most recent 3 tournaments ($p = 0.003$). Distinguishing between pool and knockout matches had no significant effect on accuracy ($p = 0.786$). Including relative home advantage within models had no significant effect on the accuracy of predictions ($p = 0.680$). The best performing individual model was VASN with 35.73 points out of 48 (74.44% correctness).

Table 2. Accuracy of pool match predictions.

Match	Model											
	VATN	VATY	VASN	VASY	VRTN	VRTY	VRSN	VRSY	SRTN	SRTY	SRSN	SRSY
Australia beat England	0.56	0.59	0.60	0.59	0.48	0.56	0.53	0.59	0.48	0.48	0.52	0.56
Australia beat Wales	0.58	0.61	0.62	0.61	0.51	0.58	0.56	0.61	0.50	0.50	0.54	0.57
Australia beat Fiji	0.87	0.88	0.88	0.88	0.88	0.88	0.89	0.89	0.86	0.86	0.87	0.87
Australia beat Uruguay	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
England lose to Wales	0.48	0.48	0.44	0.44	0.57	0.57	0.52	0.53	0.57	0.57	0.53	0.53
England beat Fiji	0.84	0.81	0.84	0.84	0.82	0.78	0.84	0.81	0.81	0.81	0.82	0.8
England beat Uruguay	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Wales beat Fiji	0.81	0.79	0.83	0.83	0.82	0.76	0.83	0.79	0.79	0.79	0.81	0.78
Wales beat Uruguay	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Fiji beat Uruguay	0.96	0.97	0.97	0.97	0.98	0.99	0.98	0.99	0.99	1.00	1.00	0.99
S.Africa beat Scotland	0.86	0.87	0.87	0.87	0.87	0.89	0.88	0.90	0.85	0.85	0.86	0.87
S.Africa beat Samoa	0.88	0.88	0.89	0.89	0.90	0.88	0.90	0.89	0.88	0.88	0.89	0.88
S.Africa lose to Japan	0.09	0.10	0.08	0.09	0.09	0.09	0.08	0.08	0.10	0.09	0.09	0.08
S.Africa beat USA	0.97	0.96	0.97	0.97	0.97	0.99	0.98	0.99	0.97	0.97	0.97	0.97
Scotland beat Samoa	0.51	0.48	0.56	0.56	0.43	0.37	0.48	0.42	0.43	0.43	0.48	0.44
Scotland beat Japan	0.54	0.52	0.58	0.58	0.46	0.42	0.5	0.46	0.46	0.46	0.5	0.48
Scotland beat USA	0.74	0.73	0.76	0.76	0.71	0.69	0.74	0.72	0.73	0.73	0.75	0.73
Samoa lose to Japan	0.48	0.47	0.44	0.44	0.57	0.54	0.52	0.50	0.56	0.56	0.52	0.52
Samoa beat USA	0.71	0.72	0.73	0.73	0.67	0.71	0.71	0.73	0.68	0.69	0.71	0.72
Japan beat USA	0.68	0.69	0.72	0.71	0.64	0.66	0.68	0.69	0.66	0.66	0.69	0.69
New Zealand beat Argentina	0.96	0.96	0.96	0.97	0.98	0.99	0.97	0.98	0.95	0.95	0.95	0.96
New Zealand beat Tonga	0.98	0.99	0.99	0.98	1.00	1.00	1.00	1.00	0.98	0.98	0.98	0.98
New Zealand beat Georgia	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
New Zealand beat Namibia	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Argentina beat Tonga	0.61	0.60	0.64	0.64	0.55	0.53	0.59	0.58	0.55	0.55	0.59	0.58

Argentina beat Georgia	0.86	0.86	0.87	0.87	0.86	0.88	0.88	0.89	0.87	0.87	0.88	0.90
Argentina beat Namibia	0.98	0.98	0.98	0.98	1.00	1.00	1.00	0.99	0.99	0.99	1.00	0.99
Tonga lose to Georgia	0.22	0.20	0.20	0.20	0.23	0.20	0.21	0.18	0.21	0.21	0.20	0.19
Tonga beat Namibia	0.95	0.96	0.96	0.96	0.97	0.97	0.97	0.97	0.98	0.98	0.98	0.98
Georgia beat Namibia	0.81	0.81	0.83	0.83	0.8	0.79	0.83	0.81	0.85	0.85	0.87	0.86
Ireland beat France	0.64	0.64	0.67	0.67	0.59	0.58	0.63	0.62	0.58	0.58	0.61	0.61
Ireland beat Italy	0.95	0.96	0.95	0.95	0.96	0.97	0.97	0.97	0.96	0.96	0.96	0.97
Ireland beat Canada	0.99	0.99	0.99	1.00	0.99	1.00	0.99	0.99	0.99	0.99	0.99	0.99
Ireland beat Romania	1.00	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
France beat Italy	0.91	0.91	0.90	0.90	0.9	0.90	0.92	0.92	0.91	0.91	0.91	0.91
France beat Canada	0.96	0.96	0.96	0.96	0.98	0.97	0.99	0.99	0.98	0.99	0.99	0.98
France beat Romania	0.97	0.97	0.97	0.97	0.98	0.99	0.99	0.98	1.00	0.99	1.00	0.99
Italy beat Canada	0.68	0.68	0.71	0.71	0.64	0.64	0.68	0.67	0.67	0.67	0.70	0.69
Italy beat Romania	0.73	0.72	0.75	0.75	0.70	0.69	0.73	0.72	0.74	0.74	0.76	0.75
Romania beat Canada	0.53	0.53	0.58	0.57	0.45	0.44	0.50	0.48	0.47	0.47	0.51	0.50
Pool match points	31.35	31.30	31.75	31.71	30.97	30.90	31.51	31.37	31.07	31.07	31.47	31.39

Table 3. Accuracy of knockout stage predictions

Fact	Model											
	VATN	**VATY**	**VASN**	**VASY**	**VRTN**	**VRTY**	**VRSN**	**VRSY**	**SRTN**	**SRTY**	**SRSN**	**SRSY**
New Zealand to reach semi finals	0.91	0.92	0.87	0.87	0.91	0.94	0.80	0.70	0.87	0.87	0.78	0.68
S. Africa to reach semi finals	0.48	0.49	0.50	0.51	0.45	0.47	0.48	0.47	0.46	0.46	0.48	0.45
Australia to reach semi finals	0.58	0.62	0.61	0.60	0.51	0.60	0.51	0.53	0.48	0.49	0.50	0.50
Argentina to reach semi finals	0.18	0.19	0.20	0.19	0.19	0.21	0.24	0.20	0.20	0.20	0.23	0.19
New Zealand to reach final	0.74	0.77	0.69	0.69	0.74	0.80	0.58	0.45	0.67	0.68	0.56	0.43
Australia to reach final	0.33	0.37	0.35	0.34	0.27	0.36	0.28	0.26	0.26	0.27	0.28	0.25
S. Africa to win Bronze final	0.22	0.23	0.22	0.22	0.20	0.22	0.18	0.16	0.19	0.19	0.18	0.15
New Zealand to win tournament	0.62	0.65	0.55	0.56	0.62	0.68	0.44	0.31	0.54	0.55	0.41	0.28
Knock out match points	4.07	4.23	3.98	3.97	3.90	4.29	3.50	3.08	3.68	3.70	3.42	2.93

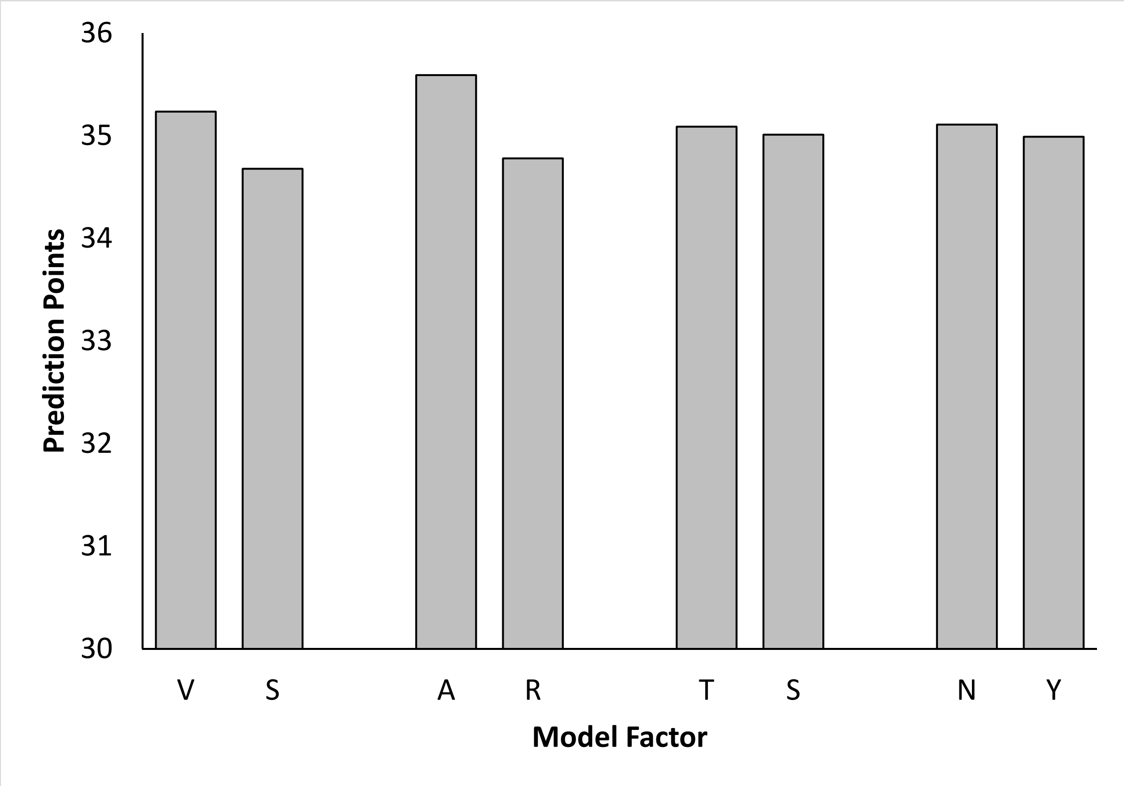


Figure 2. Accuracy of different model types (V – modelling data violate the assumptions of linear regression, S – modelling data satisfy the assumptions of linear regression, A – data from all previous Rugby World Cups used to produce the model, R – data from recent (2003-2011) Rugby World Cups used to produce the models, T – pool and knockout stage matches modelled together, S – pool and knockout stage matches modelled separately, Y – relative home advantage included, N – relative home advantage not).

Applications of the models

Team Performance

The models represent predicted points difference in matches; thus the difference between actual and predicted points differences represents how much better or worse teams performed than predicted. This allows various factors influencing performance to be investigated. Sawade (2013) recommended the use of the most accurate model available for such investigations. The difference between actual and predicted points difference values reflects how well teams performed given the quality of the opposition; this is termed relative points difference. Figure 3 shows the absolute points difference and relative points difference for each team during the tournament. This applies the best model (VASN) to the 48 matches played in the 2015 World Cup including the 8 knockout stage matches rather than matches within simulated tournaments. Figure 3 also uses error bars to show the consistency or inconsistency of teams points differences (absolute and relative) during the tournament. The horizontal values and error bars are heavily influenced by the quality of opposition. Therefore, performance is assessed using relative points difference. Uruguay was the most consistent team during the tournament while Japan was the most inconsistent. Namibia's relative performance was the best in the tournament while Tonga's was the worst. The top 7 ranked nations (New Zealand, Australia, South Africa, England, Wales, Ireland and France) are all located towards the bottom right of Figure 3 while the 16th to 20th ranked teams in the World (Georgia, Romania, Canada, Uruguay and Namibia) all have positive relative PD values. This is evidence that the gap between the highest and lowest ranked teams in the tournament has reduced during the tournament.

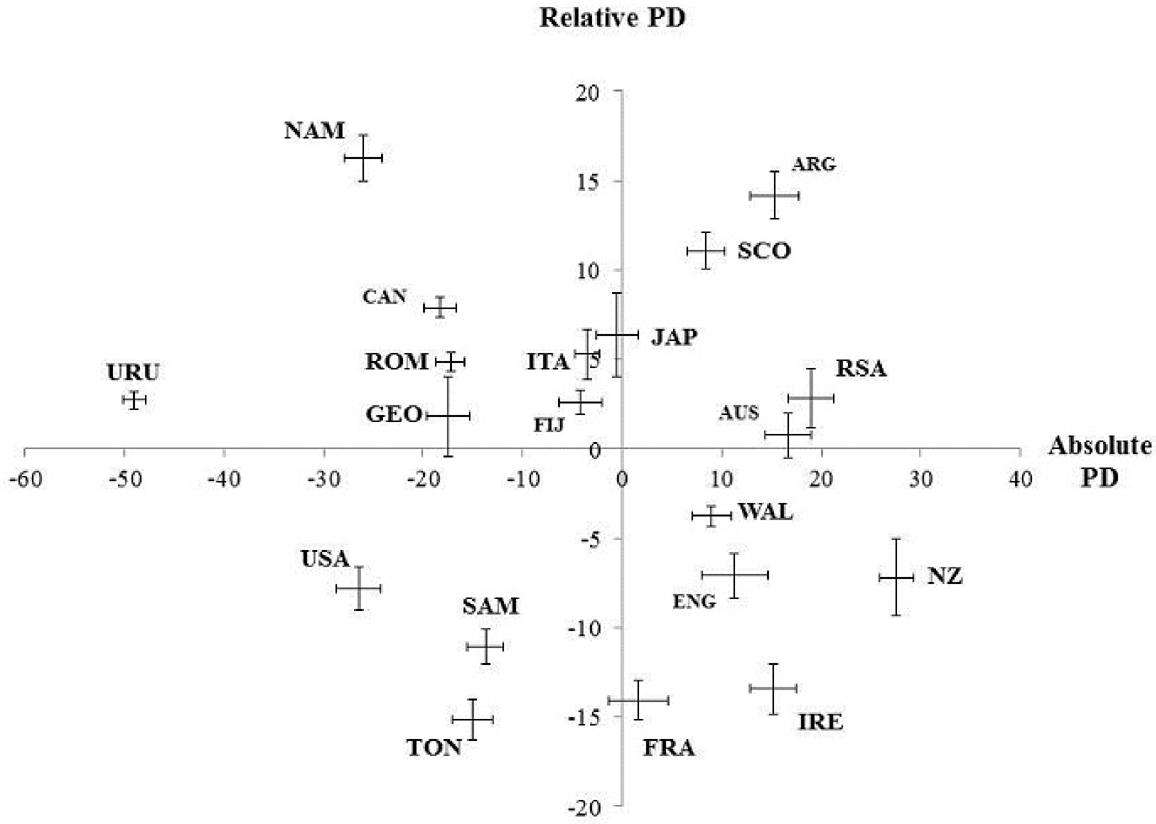


Figure 3. Absolute and relative points difference for each team during their matches of the 2015 Rugby World Cup. Error bard represent SD / 10.

Tournament Structure

Simulating tournaments does not give a definitive prediction of what will happen in the tournament. Variation from predicted results is possible and unexpected results occur in sport. A team's World ranking is changed after each match using a recursive method that applies ranking adjustments to their World rankings prior to the match. This means that World rankings reflect team performance over a period of time with recent performances weighted higher than previous performances. Therefore, World rankings cannot be expected to accurately predict outcomes of all individual fixtures. The information produced by simulating tournaments can be thought of as probabilities of match outcomes and teams' progressions. The simulation statistics represent how well teams were predicted to do given their World rankings, the World rankings of their opponents in the pool stage matches and the World rankings of their likely opponents if they proceeded to the knockout stages. This information can be useful in the design of tournaments to look at the impact of alternative tournament structures. For example, O'Donoghue (2005a) used simulation to show how the "back door" system in the All-Ireland Senior Gaelic Football Championship increased the likelihood of stronger teams getting the semi-finals and final. The main issue with the 2015 Rugby World Cup was that the draw for the tournament was made three years earlier when Wales were ranked 9^{th}. Teams' World rankings changed in the years leading up to the tournament. When the tournament commenced, three of the World's top 5 teams and four of the World's top 9 teams were in Pool A. Figure 4 uses colours from Blue to Magenta to represent the strength of teams in the different pools. The fact that three closely ranked teams were placed in Pool A, not only reduced their chances of winning the tournament but also increased the chances of some lower ranked teams winning the tournament, especially Ireland. This calls into question the fairness of making the draw so early. A tournament is considered fair if teams' chances of winning are ordered the same as team quality.

Pool A	Pool B	Pool C	Pool D
Australia	South Africa	New Zealand	Ireland
England	Scotland	Argentina	France
Wales	Samoa	Tonga	Italy
Fiji	Japan	Georgia	Romania
Uruguay	USA	Namibia	Canada

Figure 4. Using colour to visualise quality of teams within each pool.

Figure 5 shows the modal prediction derived from statistics accumulated during 100,000 simulations of the Rugby World Cup based on the most accurate of the 18 models (VASN). The percentages shown are for the named teams reaching the given stages of the knockout tournament. However, in some cases the modal team reaching a given stage of the tournament did so in fewer than 50% of simulated Rugby World Cups. Therefore, the blue to magenta colour scale is used to represent the World ranking of the mean team reaching each stage of the knockout structure. According to this model, New Zealand were the most likely team to win the tournament (55.4% of simulated tournaments) followed by Australia, the World's number 2 ranked team (14.1%). However, Ireland who were ranked 6th in the World were the third most likely team to win the tournament (8.0%) followed by South Africa (7.4%), England (6.6%) and Wales (5.0%) who were ranked 3rd, 4th and 5th in the World respectively at the start of the tournament. What this analysis of the simulation data has shown is that the chances of Australia, England and Wales progressing were reduced by their being drawn in the same pool. At least one of these three teams would be eliminated before the knockout stages of the tournament. All three teams' chances of qualifying for the knockout stages were split between the top and bottom halves of the draw due to there being no clear cut favourite to win Pool A as there was in the other three pools. Finishing second in Pool A and entering the top half of the knockout tournament would impact on the teams' chances of progressing to the final because New Zealand and South Africa (ranked 1st and 3rd in the World) were predicted to compete in the top half of knockout tournament. Ireland, on the other hand, were likely to win Pool D. The difference between Ireland's 84.40 World ranking points and France's 81.12 was similar to the gap between 2nd ranked Australia (86.67 World ranking points) and Ireland. The winner of Pool D was due to play the runner up from Pool C in a quarter final. The runner-up of Pool C had a mean World ranking of 77.7 World ranking points giving Ireland more of a chance of making the semi-finals than South Africa. Australia did have a higher chance of reaching the semi-finals than Ireland because they reached the semi-final in the top half of the knockout structure in 18.4% of simulated tournaments in addition to the 42.2% of simulated tournaments where they reached the semi-final in the bottom half of the knockout structure. However, there were 9 of the 18 models where Ireland reached the final more often than Australia during the simulations. A fairer tournament should ensure pools contain one team ranked between 1 and 4 in the World, one team ranked between 5 and 8 in the World, one ranked 9 to 12, one ranked 13 to 16 and one ranked outside the World's top 16.

The use of colour in Figures 4 and 5 helps readers visualise important aspects of the tournament structure. Such an approach could be expanded into an analytics approach if an interactive tool allowed tournament designers to adjust models and expect areas of the knockout structure to identify individual team chances of progressing. Such a tool could support tournament design meeting in real time, if "what if" scenarios could be introduced flexibly leading to rapid production of team progress charts with visual impact facilitating decision making.

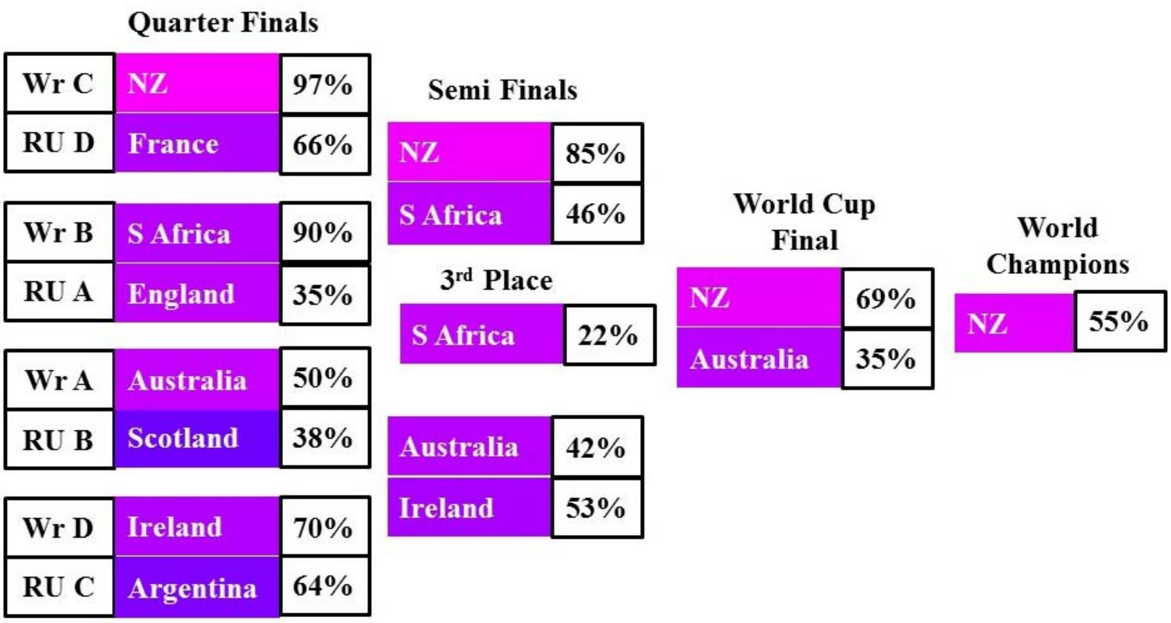


Figure 5. Modal prediction from 100,000 simulations of the VASN model.

Recovery Days

A further issue with the design of the Rugby World Cup is that there are 5 teams in each pool which will mean there are matches where the two teams will have differing numbers of recovery days from their previous matches. The models allow the impact of differing recovery days to be determined taking into account the quality of the teams contesting each match. The difference between a team's actual PD value in a match and the predicted PD value according to the best model (VASN) represents how many more points the team scored than predicted within the match. There were 34 of the 48 matches in the 2015 Rugby World Cup where one team had more recovery days than their opponents. The points difference for the team who had more recovery days from the previous was 10.1 ± 30.0. The predicted points difference for these teams, according to the VASN model was 6.0 ± 31.0. Therefore, teams with more recovery from the previous match than their opponents had performed better than predicted by 4.1 ± 16.3 points. The effect of additional recovery days over the opponent was small (Cohen's $d = 0.134$) but not significant ($t_{33} = 1.5$, $p = 0.153$).

Discussion

The most accurate predictive model achieved an evaluation score of 35.73 out of 48 (74.4%). When this is compared to studies predicting previous Rugby World Cups there is evidence that international Rugby Union is becoming more difficult to predict. The best performing model in O'Donoghue and William's (2004) study of the 2003 Rugby World Cup achieved 92.7% of the marks available using the same evaluation scheme. A regression based model with threshold values adjusted to predict the proportion of upsets evidenced by previous match results had an accuracy score of 78.1% for matches in the 2007 Rugby World Cup (O'Donoghue, 2009). A simulation model where data satisfied the assumptions of linear regression was the most accurate prediction of the 2011 Rugby World Cup scoring 36.8 out of 48 points (76.7%) (O'Donoghue, 2012a). The gradual reduction in prediction accuracy over these 4 tournaments may be explained by growing strength in depth of international rugby union. In 2011, Tonga were the 4th ranked team in their pool but caused an upset by defeating France who were the 2nd ranked team. In 2015, Japan were the 4th ranked team in their pool and caused upsets by defeating the 1st and 3rd ranked teams (South Africa and Samoa). Despite the number of upsets and the reduced accuracy of prediction compared with previous Rugby World Cups, international rugby matches are still more predictable than international soccer matches. O'Donoghue (2014) reported the highest accuracy of 12 models used to predict the 2014 FIFA World Cup to be 27.0 out of a possible score of 64 (42.2%). The main issues with soccer is that there is greater strength of depth, more upsets and the number of drawn matches within the pool stages is much greater than in rugby World Cup tournaments.

Having argued that the nature of rugby union is changing and becoming more unpredictable, one might expect that predictive models based on more recent data would be more accurate than models including dated cases. Menon et al. (2014) stated that models based on more recent data were more credible than using more dated data. However, the four models based on data from all previous Rugby World Cups received significantly more evaluation points on average than the 8 models based on data from just the 2003 to 2011 tournaments. The models based on all previous tournaments were more likely to predict that higher ranked teams would progress in the knockout stages than their lower ranked opponents. This meant that they only performed worse than models based on more recent data in the prediction of the Ireland v Argentina quarter final. There was a similar pattern in the pool matches but with some variability. Thus the current investigation suggests that models created using a larger volume of historic cases are more accurate than when data sets are restricted to more recent cases.

Evaluation scores were slightly lower when relative home advantage was included in the models. This suggests that home advantage does not have an influence on the outcome of international Rugby Union matches. Eight Rugby World Cups have now taken place with the host nation winning three of these while the remaining five tournaments have been won by teams from other continents. A possible explanation for the lack of a relative home advantage effect is that teams stay in the host nation of the tournament for a long period; the 2015 Rugby World Cup lasted 43 days with most travelling teams arriving sufficiently early to allow acclimatisation and recovery from jet lag and travel fatigue prior to the tournament commencing. The limitations of the relative home advantage measures used also need to be acknowledged. They do not account for the countries where players compete in domestic competition and distances are used without considering how many or few time-zones are crossed.

On average, producing separate models for pool and knockout stage matches did not lead to more accurate predictions than using the same model for both types of match. One explanation for this is that there are very few draws in international rugby union matches. This may influence the way teams play knowing that one or other team will probably win the match. In soccer draws are more common and there may be pool matches where teams play more cautiously where it is more important not to lose than to win. Another explanation for the greater accuracy of models that consider pool and knockout matches together is that some pool matches have similar characteristics to knockout matches. There were a number of matches like this in the 2015 Rugby World Cup including the matches between England and Wales, Australia and England, Australia and Wales, South Africa and Scotland, Scotland and Japan, Scotland and Samoa as well as Ireland and France. The Pool A matches involving Australia, England and Wales were vital because only two teams could qualify from the pool. Once South Africa had lost to Japan, a further loss against Scotland could have eliminated them from the tournament. On the other hand, once Japan had defeated South Africa, a further win against Scotland would give them a very high chance of qualifying from Pool B. Ireland and France had already qualified from Pool D by the time they played each other. However, the loser of this match would have to play the top ranked team, New Zealand, in the quarter finals, something that both teams would seek to avoid.

Despite the average results where pool and knockout matches were considered together or separately, the best performing individual simulation was one where separate models of pool and knockout stage matches were used. The VASN model weighted each World ranking points as being worth 2.4 points in a pool match but only 1.2 points in a knockout match. Another difference in this simulation model was the more consistent simulated results of knockout matches compared to pool matches. This agrees with the general concept that there are differences between matches played at different tournament stages (Sampaio and Janeira, 2003; Garcia et al., 2013; Triniz et al., 2002).

The current study does not justify the effort required to transform data so that they satisfy the assumptions of modelling techniques being used. Indeed the predictions made using models created using data that satisfied the assumptions were significantly less accurate than models made using untransformed data. This agrees with previous research in both soccer (O'Donoghue, 2005b, 2006, 2010, 2014) and rugby (O'Donoghue, 2009). There was a study of the 2011 Rugby World Cup where models based on data satisfying the assumptions were slightly more accurate than when untransformed data were used (O'Donoghue, 2012a). However, the difference was marginal and did not justify the effort made to satisfy the assumptions. The current study suggests that linear regression is robust to violations of the assumptions of the technique by the type of data used in the current investigation.

The current study found a small effect of having more recovery days than the opposition from the previous match. There were 7 matches within the 2015 Rugby World Cup where one of the teams had 4 or more additional recovery days than the opponent from their previous games. The Rugby World Cup consists of 4 pools of 5 teams meaning that some teams are not involved in a pair of fixtures and therefore get extra recovery days over their opponents in the next match. Fixture congestion can contribute to injury, fatigue and poor performance (Dupont et al., 2010). Rugby union involves impact and collisions that players need to recover from. Further research has found that limited recovery can decrease physical capacity and affect the decision making and skill execution (Gabbett, 2008; Lyons et al., 2006, Royal et al., 2006). Recognition of fatigue effects and associated risks have encouraged the monitoring of individual players (Carling et al., 2015).

Conclusions

The current investigation has found that match outcomes in international rugby union performance are more difficult to predict than in previous years. The most accurate model was created using data from all previous Rugby World Cups that violated the assumptions of linear regression. This model did not include relative home advantage which was not a significant predictor of match outcome. The simulations used separate underlying regression models for the pool and knockout stage matches. The effort of transforming data to satisfy the assumptions of linear regression cannot be justified by the current investigation. Larger data sets produce more accurate predictive models than smaller sets of more recent data. The model allowed the tournament structure to be investigated revealing the unfairness of making the draw three years before the tournament. A team ranked 6th in the World had more of a chance of the teams ranked 3rd to 5th who were all drawn in the same pool. The model also allowed teams' performances to be evaluated considering the quality of opposition faced in matches. This revealed that higher ranked teams did not do as well as predicted while the lowest ranked 5 teams did better than predicted. Therefore, the gap between the higher and lower ranked teams in Rugby World Cup tournaments has closed in the 2015 tournament. Addressing opposition quality also determined that having additional recovery days over the opponents since the previous matches benefitted teams by an average of 4.1 points within matches.

References

Allison, P.D. (1999). *Multiple regression: a primer*. Thousand Oaks, CA: Pine Forge Press.

Anderson, D.R., Sweeney, D.J. and Williams, T.A. (1994). *Introduction to statistics: concepts and applications*. 3rd edn, Minneapolis / St Paul: West Publishing Company.

Carling, C., Gregson, W., McCall, A., Moreira, A., Wong, D.P., and Bradley, P.S. (2015). Match Running Performance During Fixture Congestion in Elite Soccer: Research Issues and Future Directions. *Sports Medicine, 45*, 605-613.

Condon, E. M., Golden, B. L., & Wasil, E. A. (1999). Predicting the success of nations at the Summer Olympics using neural networks. *Computers & Operations Research, 26*(13), 1243-1265.

Courneya, K.S. and Carron, A.V. (1992). The home advantage in sports competitions: a literature review. *Journal of Sport and Exercise Psychology, 14*, 13-27.

Dupont, G., Nedelec, M., McCall, A., McCormack, D., Berthoin, S., and Wisløff. (2010). Effect of 2 Soccer Matches in a Week on Physical Performance and Injury Rate. *The American Journal of Sports Medicine, 38*(9), 1752-1758.

Gabbett, T.J. (2008). Influence of fatigue on tackling technique in rugby league players. *Journal of Strength and Conditioning Research, 22*(2**)**, 625-632.

Garcia, J., Ibáñez, S.J., Martinez De Santos, R., Leite, N., & Sampaio, J. (2013). Identifying Basketball Performance Indicators in Regular Season and Playoff Games. *Journal of Human Kinetics, 36*, 161-168.

Gómez, M-Á., Lago-Peñas, C. and Pollard, R. (2013). Situational variables**.** In McGarry, T., O'Donoghue, P.G. and Sampaio, J. (eds.), *Routledge Handbook of Sports Performance Analysis* (pp. 259-269). London: Routledge.

Herzog, S. and Hertwig, R. (2011). The wisdom of ignorant crowds: Predicting sport outcomes by mere recognition. *Judgement and Decision Making, 6*(1), pp. 58-72.

Indonesia (2014). www.indo.com/distance, accessed June 2014.

Kiesel, K. B., Butler, R. J., & Plisky, P. J. (2014). Prediction of injury by limited and asymmetrical fundamental movement patterns in American football players. *Journal Of Sport Rehabilitation, 23*(2), 88-94.

Kleinbaum, D., Kupper, L., Nizam, A. and Rosenberg, E. (2013). *Applied regression analysis and other multivariable methods*. South Melbourne, Victoria, Australia: Cengage Learning.

Kuhn, M and Johnson, K., (2013). *Applied practice modelling*. London : Springer Science And Business Media.

Lyons, M., Al-Nakeeb, Y. and Nevill, A. (2006). The impact of moderate and high intensity total body fatigue on passing accuracy in expert and novice basketball players. *Journal of Sports Science and Medicine, 5*(2), 215-227.

McGarry, T., & Franks, I. M. (1994). A stochastic approach to predicting competition squash match-play. *Journal of Sports Sciences, 12*(6), 573-584.

McHale I, Davies S (2007) Statistical analysis of the FIFA world rankings. In R. Koning and J. Albert (eds.), *Statistical thinking in sport* (pp. 77-90). Boca Raton: Chapman and Hall.

Menon, M.E., Terkla, D.G. and Gibbs, P. (2014).*Using data to improve higher education: Research policy and practice*. London: Springer .

Newell, J., Aitchison, T. and Grant, S. (2010) *Statistics for sport and exercise science: a practical approach.* Harlow, UK: Prentice Hall.

Ntoumanis, N. (2001), *A step-by-step guide to SPSS for sport and exercise studies*. London: Routledge.

O'Donoghue, P.G. (2005a). The Role of Simulation in Sports Tournament Design for Game Sport. *International Journal of Computer Science in Sport, 4*(2), 14-27.

O'Donoghue, P.G. (2005b). Evaluation of Computer-based Predictions of the Euro 2004 Soccer Tournament. 5th International Symposium of Computer Science in Sport, Hvar, Croatia, 25th-28th May, Book of abstracts, pp.36.

O'Donoghue, P.G. (2006). The effectiveness of satisfying the assumptions of predictive modeling techniques: an exercise in predicting the FIFA World Cup 2006. *International Journal of Computing Science in Sport, 5*(2), 5-16.

O'Donoghue, P.G. (2009). Predictions of the 2007 Rugby World Cup and Euro 2008. 3rd International Workshop of the International Society of Performance Analysis of Sport, Lincoln, UK, 6th-7th April 2009.

O'Donoghue, P.G. (2010). The effectiveness of satisfying the assumptions of predictive modelling techniques: an exercise in predicting the FIFA World Cup 2010. *International Journal of Computer Science in Sport, 9*(3), 15-27.

O'Donoghue, P.G. (2012a). The Assumptions Strike Back! A comparison of prediction models for the 2011 Rugby World Cup. *International Journal of Computer Science in Sport, 11*(2), 29-40.

O'Donoghue, P.G. (2012b). *Statistics for sport and exercise studies: an introduction*. London: Routledge.

O'Donoghue, P.G. (2014). Factors influencing the accuracy of predictions of the 2014 FIFA World Cup. *International Journal of Computer Science in Sport, 13*(1), 32-49.

O'Donoghue, P.G. and Williams, J. (2004). An evaluation of human and computer-based predictions of the 2003 rugby union world cup. *International Journal of Computer Science in Sport, 3*(1), 5-22.

O'Donoghue, P.G., Dubitzky, W., Lopes, P., Berrar, D., Lagan, K., Hassan, D., Bairner, A. and Darby, P., (2004). An Evaluation of quantitative and qualitative methods of predicting the 2002 FIFA World Cup. *Journal of Sports Sciences, 22*, 513-514.

Pollard, R. and Gómez, M. A. (2009). Home advantage in football in South-West Europe: Long-term trends, regional variation, and team differences. *European Journal of Sport Science, 9*, 341-352.

Pollard, R. and Pollard G. (2005). Long-term trends in home advantage in professional team sports in North America and England (1876–2003). *Journal of Sports Sciences, 23*, 337–350.

Royal, K.A., Farrow, D., Mujika,I., Halson, S.L., Pyne, D. and Abernethy, B. (2006). The effects of fatigue on decision making and shooting skill performance in waterpolo players. *Journal of Sports Sciences, 24*(8), 807-815.

Sainani, K. L. (2014). Explanatory versus predictive modelling. *Physical Medicine and Rehabilitation, 6*(9), 841-844.

Sampaio, J. and Janeira, M. (2003). Statistical Analyses of Basketball Team Performance Understanding Teams' Wins and Losses According to a Different Index of Ball Possessions. *International Journal of Performance Analysis in Sport, 3*(1), 40-49.

Sawade, (2013). Active evaluation of predictive models. Berlin : University Verlag Potsdam .

Stefani, R. (1998). Predicting Outcomes. In J. Bennett (ed.), *Statistics in Sport* (pp.249-275). London: Arnold.

Tabachnick, B. G., & Fidell, L. S. (2001). *Using multivariate statistics*. Boston: Allyn and Bacon.

Tabachnick, B.G. and Fidell, L.S. (2007). *Using multivariate statistics, 5th Edition*. Boston : Pearson/Allyn & Bacon.

Trninic, S., Dizdar, D., & Luksic, E. (2002). Differences between Winning and Defeated Top Quality Basketball Teams in Final Tournaments of European Club Championship. *Collegium Atropologicum, 26*(2), 521-531.

Vincent, W. (1999). *Statistics in Kinesiology, 3rd Edition*. Champaign, Il: Human Kinetics Publishers.