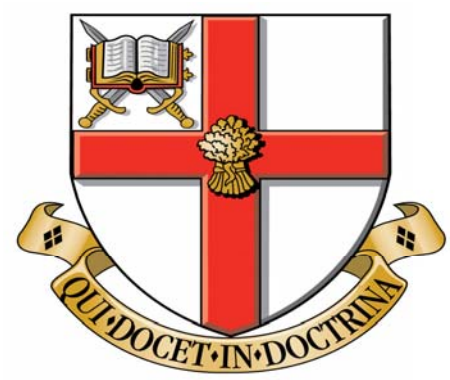


University of Chester

# Exploratory Analysis of Goalball:

# A Regression Based Approach

**by**

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No portion of the work referred to in this Research Project has been submitted in support of an application for another degree or qualification of this, or any other University or institute of learning.

The project was supervised by a member of academic staff, but is essentially the work of the author.



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***An Exploratory Analysis of Goalball – A Regression Based Approach***

The purpose of the study was to identify whether there was a relative quality effect for key performance indicators (KPI) in goalball. The study was completed from a performance analysis perspective and analysis was completed on two major international goalball tournaments (Paralympics 2012, European A 2013) and three IBSA qualifying events (Hungary 2013, Venice 2014, Malmo 2014). A regression-based analysis described by O'Donoghue & Cullinane (2011) was used to identify whether there was a relative quality (RQ) effect between KPI in goalball. Results showed that there was a low correlation between RQ and KPI in goalball. Although weak positive correlation was observed, a repeated measures anova showed trends for shots to pockets ($F=3.280$, $p=0.053$) and speed of shot ($F=4.048$, $p<0.05$), with a weak negative correlation for smooth shots ($F=5.598$, $p<0.05$). Thus, suggesting that teams of higher RQ score more goals, through faster more accurate shots. The regression was used to present a case study from one match between Russia and GB (RQ of +1.12, -1.12 respectively). The team with higher RQ performed well in desirable aspects of performance, exceeding the performance of 81.30% for speed of shot, 94.36% shots to pockets and 70.63% bounce shots of performances with that RQ. Despite the low correlation between RQ effect and KPI in goalball the regression-based analysis was shown to have an applied application, although caution would be expressed due to the variation experienced in the upper and lower estimates of the prediction equation.

## 1. Introduction

Goalball was invented in 1946 in an effort to help the rehabilitation of blinded war veterans (International Blind Sports Federation, 2014). Goalball is a team sport designed for the blind and visually impaired and it was introduced to the Paralympics in 1976, featuring at every subsequent Paralympic Games and World Championships since (IBSA, 2014).

Goalball is a unique ball game in the sense that only blind participants partake in the sport. The game consists of two teams of three players and a maximum of three substitutes, played on a modified volleyball court (Appendix 1) with tactile markings allowing the players to determine their location (Colak, Bamac, Aydin, Meric, & Ozbek, 2004). The purpose of the game is to outscore the opposition by throwing the goalball by hand, past the goal line of the opponent's team area (Davis, 2011). Players attempt to prevent the ball crossing their goal line by diving for the ball and using their body to block the ball. The ball is made of hard rubber containing embedded bells to create sound projected by movement, thus allowing the players to track and locate the ball audibly (Colak et al., 2004).

The limited body of research available regarding the sport contained work in a range of disciplines including physiological, biomechanical and performance analysis (PA), however, the depth was limited in all disciplines. Previous research of goalball related to the proposed study involved the characterisation of behavioural patterns and offensive actions of goalball

(Amorim, Botelho, Sampaio, Saorin & Corredeira, 2010). Amorim et al. (2010) found that significantly more shots were directed toward the right and left zones compared to the centre, despite players typically located at such positions. However, this was based on a simplified division of the zones, which are usually divided into seven sections (Appendix 2). Furthermore, Amorim et al. (2010) also reported basic attempts at KPI when concerning the type of throws. Although some attempt was made to classify operational definitions for some of the types of throws, the definitions were not only unclear but did not conform within the expected types of throw that would usually be observed, such as the smooth, bounce, bounce-rotation and rotation shots (Appendix 6, Goalball UK, 2014), making replication of the study unachievable. The seven-sector division is common practice within the sport and is the method used by all international teams (Morato, 2012). Alongside the unclear definitions of throw types, the methodology used was also a limiting factor of the research of Amorim et al. (2010), because it only included five Portuguese domestic clubs, of which no influence of the opposition was taken into account, causing issue as the level of opposition has been proven to impact the performance of the team and resultant KPI values (Lago, 2009). Further, no comparison was presented to suggest whether such findings were related to successful performance, therefore the results could not be interpreted and feedback could not be presented in attempt to improve performance (Mackenzie & Cushion, 2013).

Alternatively Lehto, Hayrinen, Laitinen and Collen (2012) assessed the type of throw used in relation to winning and losing performance. Finding that winning

teams achieved significantly more successful throws (4.6% vs. 2.6%, $p<0.01$) and significantly less error [foul] throws (1.0% vs. 1.5%, $p <0.01$). Furthermore, Lehto et al. (2012) found that winning teams scored significantly more goals with flat [smooth] throws than losing teams (71.5% vs. 47.0%, $p<0.05$). Therefore, Lehto et al. (2012) concluded that the ability to throw powerful and accurate flat throws was key to winning elite women's goalball matches. However, a limitation of the study was that the conclusion was presented without evidence, suggesting that a powerful throw was required, despite there being no evidence reported to suggest that power or speed was assessed within the research.

In comparison, Bowerman, Davis, Ford and Nichols (2011) compiled a comparative biomechanical analysis of the phases of movement of two goalball throws, the traditional shot and the spin shot. The types of shot were then analysed in relation to ball velocity and the phases of movement within the study, which included the preparatory, approach (wind up and delivery) and the follow through phases. Results of the study found the spin (rotation) shot to produce a greater velocity ($26m.s^{-1}$) than the traditional throw ($21m.s^{-1}$). Further breakdown produced corresponding results with both men and women generating more velocity from the spin throw, although there was only a $1ms^{-1}$ difference between the women's mean throws and no significant difference was found. The velocity was measured through dividing the distance of the neutral area (6m) by the time, which was measured by counting the number of frames from the video footage and dividing that number by the digital recording frame rate (60frames/s) (Bowerman et al.,

2011). However, a limiting factor of the research was that the participants used were sub-elite level athletes, and furthermore, there was no comparison to any other nation to suggest whether this had any impact on success, or whether the values were consistent within the sport. Further, the use of the 6m lines for the throw could have been a limiting factor, as if any throw was made at an angle the distance would change. Comparisons would have been required to assess whether shot velocity was a determining factor between successful and unsuccessful nations, as Lehto et al. (2012) found statistical difference between winners and losers for certain KPIs. However, the velocity of the shot was not researched and therefore was not able to state whether this aspect of performance had an impact on success, consequently subsequent differences may have been attributed to shot velocity rather than KPIs reported.

A further area of research into goalball was based around the influence reaction time had on the efficiency of defence action and Silva et al. (2010) found that the reaction time of the goalball athletes was higher than the average population of the visually impaired public, showing that goalball can improve reaction time. Similarly, Duarte Costa, Moura, Pereira and Castro (2003) concluded that goalball athletes outperformed other disciplines of athletes in relation to reaction time, suggesting that the specific modality for people with visual disabilities requires good auditory perception, subsequently aiding the reaction time when audibly identifying the sound of the ball within the game, generating improvement in response actions. Duarte Costa et al. (2003) suggested that this might have been due to the reliance on auditory

perception in daily life that improved the reaction time of the goalball players in comparison to those in other sports. Nevertheless, although only a small difference was observed, it was found that when actions resulted in the defence of the ball, subjects responded faster and more efficiently in the work of defence than when actions resulted in a goal (Silva el., 2010). However, only ten trials were conducted, which Silva et al. (2010) stated was insufficient to induce fatigue in the athlete and interfere with reaction time, consequently meaning the research was not representative of match performance. A further limitation of the study was that although Silva et al. (2010) stated that the task was insufficient to induce fatigue, there was no mention of measurement of fatigue during the testing. This could have been done through a simple measure of muscle function (i.e. jump height) that would have been able to determine whether fatigue was actually present (Twist & Highton, 2013). Furthermore, due to the research being a case study of the Brazilian national team, there was no suggestion as to the influence the findings would have had on success, as the results were not compared to any other nation or successful performance. Furthermore there was no inclusion of the effect of the quality of throw or opposition influencing the reaction time.

PA has been used previously to report the findings of goalball performance. Lehto at el. (2010) compared the men and women's game finding a trend between the number of shots taken per game (men: 79.8± 4.4; women: 76.0± 4.8, p=0.06). However, when looking at the statistics produced, Lehto et al. (2010) were able to draw the conclusion that the greater number of shots witnessed in the men's game suggested that elite level men's goalball was

played at a faster pace than women's, despite the confining rule of having ten seconds to complete each throw. Furthermore Lehto et al. (2010) analysed the breakdown of how goals were scored during a game, with 85.2% of goals being scored with normal [smooth] throws and 14.8% with penalty throws within the women's game. Furthermore, women were observed to concede a higher percentage of goals when defending with their hands (47.9% ± 37.1%) and torso (16.2% ± 31.0%) than at their feet. Were as men conceded more defending with their feet (53.4 ± 21.4%) than hands or torso. (Lehto et al., 2010). Although the findings would have benefited from further detail such as where the goals were scored or whether successful teams scored more goals in a particular manner, an overall tactical understanding of the sport can be obtained through the use of PA in goalball.

Similarly, Lehto et al. (2010) used PA in goalball to assess the impact of how goals were scored. In contrast, Lehto et al. (2012) related the information to winning and losing performances as well as providing more detail about the type of shot used, providing a greater understanding about the performance, although further understanding could have been produced by taking into account the level of opposition as appose to simply winning or losing teams. Lehto et al. (2012) found that winning teams scored significantly ($p<0.05$) more goals implementing the flat [smooth] throw (71.5%) compared to losing teams (47.0%). However, taking in to account the level of opposition the goals were scored against to assess whether there was a tactical difference dependent on the quality of opposition and further contextual information about the performance would have lead to greater understanding. Despite the

limitations of previous research, PA has been able to provide a tactical understanding about goalball performance that could feedback useful information to players and coaches.

However, Mackenzie and Cushion (2013) have recently criticised PA research, specifically in football in the sense that the research does not provide enough contextual information about the performance, such as the location of the match, the area on the pitch where events occurred and the strength of opposition. Additionally, Mackenzie and Cushion (2013) suggested that international tournaments present scenarios that are non-representative, in the sense that teams of distinct quality differences play against each other in group and knock out formats and therefore successful teams may approach such contests in an alternative manner, such as being more offensive against weaker opposition, providing alternative results in terms of KPI in relation to the context of the game. Furthermore, the influence of opposition has been identified as a limiting factor associated with contextual information, as the influence of the opposition directly influences the findings of the study (Mackenzie & Cushion, 2013). Mackenzie and Cushion (2013) stated that by incorporating contextual information when reporting data about the performance, a more holistic understanding of the influence the variable may have had on the outcome could be attained.

Previous methods of assessing the quality of opposition have used a median split technique or a ‘top v bottom’ comparison (O’Donoghue, 2008; O’Donoghue, Mayes, Edwards & Garland, 2008; Lago-Penas, Lago-

Ballesteros, Dellal & Gomez, 2010). However, a criticism of this approach was that the method assumes that all of the teams in a given quality grouping are of a similar ability (O'Donoghue & Cullinane, 2011). The advantage of using a regression-based approach to assess RQ was the allowance of KPI values to be compared with expected values for the given strength of an opponent (O'Donoghue & Cullinane, 2011). The regression-based approach has been developed to assess RQ as O'Donoghue (2009) stated that KPI are influenced by the quality of the opposition, although recent methods for assessing the effect of quality have been criticised. As O'Donoghue and Cullinane (2011) suggested that a value for a KPI representing a good performance against a strong opposition may not represent a good performance against weaker opposition. Therefore the current study will make attempt to address such issues by adopting the methods of O'Donoghue and Cullinane (2011) through a regression-based approach to the relative quality (RQ) of the opposition.

The purpose of the study was therefore to attempt to develop an understanding of the technical and tactical aspects of goalball performance associated with successful performance. Through the identification of the areas that lead to successful performance in goalball by identifying KPI where goals are scored (shot direction) and how they are scored (shot type/shot speed) and the association with winning teams. Further the impact of the velocity of the shot to provide substance to the previously hypothesized impact on successful performance. Finally, to identify whether there was a relative quality effect for KPI in goalball.

## 2. Methods

### *2.1 Participants*

A projected sample size of 44 matched was predicted using a G*power calculation (Beck, 2013). The recruited participants of the study consisted of 53 matches containing 106 team performances of elite level Women's International Goalball teams that participated in the two most recent major international tournaments (London Paralympic Games, 2012; Turkey European A Championships, 2013) as well as the most recent IBSA qualifying events (Hungary, 2013; Venice, 2014; Malmo 2014). Ethical approval was obtained before commencing the study, with consent gained from the governing body of the sport and confidentiality maintained throughout (Appendix 8). The distinctive characteristics of the participants included elite level athletes that were all visually impaired. IBSA (2014) states that all athletes that participate within the sport have to have a visual impairment ranging from B1 to B3. Colak et al. (2004) explains the classification of blind/visually-impaired athletes as suggested by USABA (The United States Association of Blind Athletes) as follows:

- B1 – No functional vision
- B2 - a visual acuity of less than 20/400 or a visual field of less than 5°
- B3 – visual acuity of 20/200 – 20/400 or a visual field of 5-20°

In order to justify the number of trials used to calculate the speed of shot sequential analysis was used, determining the point of mean stability for the number of shots analysed (Taylor, Lee, Landeo, O'Meara & Millet, 2014). A sample of 40 shot speeds for one team was used to determine the mean, cumulative mean and ± 0.25 standard deviations (s) to create the upper and lower bandwidth. A sequential analysis score (trials to stability) of five was produced, as this was the point that the cumulative mean rested within the bandwidth. Therefore five trials were used per team, per match to assess shot speed.

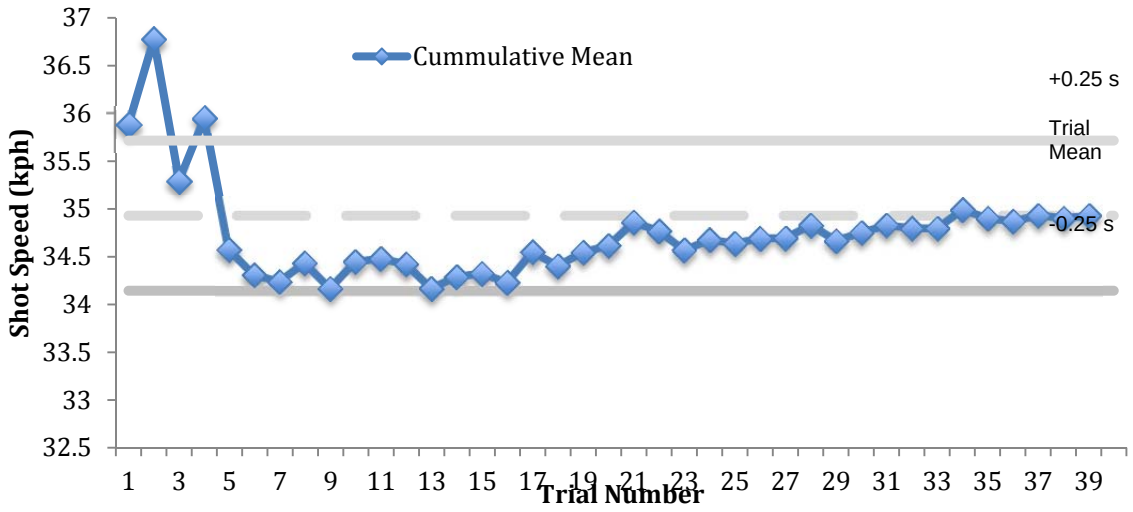


Figure 1. Sequential Analysis of the number of shots required for shot speed.

### *2.2 Design*

The study was an independent samples design of experimental research, based upon identifying a RQ effect in goalball. The variables that will be measured include (Appendix 4):

- **Independent variable (IV):** the RQ of the team and opposition
- **Dependent variables (DV):** goals scored and conceded, shot type, shot direction and speed of throw.

### *2.3 Procedures*

Data was collected through video captured at international goalball tournaments attended by the researcher. The subsequent footage was analysed using Dartfish analysis software (Dartfish 4.0, Lausanne, Switzerland) through the creation of a template to analyse the KPI. The methodology of O'Donoghue and Cullinane (2011) was then applied to the data to form the regression-based approach to RQ. The World Ranking (Appendix 5) of each nation was transformed into a RQ using the formula developed by Klassen and Magnus (2001):

$$RX = 8 - \log2(RankX)$$

This produced an estimate for the round of the competition that the team was expected to finish. The RQ of each team was calculated using the following formula:

$$RQ = RX - RY \text{ (for team X and team Y)}$$

E.g. RQ = RX (team ranked $2^{nd}$) – RY (team ranked $8^{th}$)

$$RQ = 4 - 2$$

Team X RQ = +2  Team Y RQ = -2

Once the results of the data analysis were completed correlations were calculated between each measured KPI and RQ, this plotted the KPI against the quality of opposition (O'Donoghue & Cullinane, 2011).

Figure 2. Relationship between %first serve in and RQ (O'Donoghue & Cullinane, 2011).

From the example presented in Figure 2 a line of best fit was drawn using the SLOPE and INTERCEPT functions of Microsoft Excel as highlighted in the top left hand corner of Figure 2. It was then be possible to obtain residual values (RV) by identifying the observed score from the analysis and expected score from the regression equation.

$$RV = \text{Observed Score} - \text{Expected Score}$$

This represented how a team performed compared to how they were expected to perform against a team of that World Ranking (O'Donoghue & Cullinane, 2011). Following this an Evaluation Score (ES) was calculated

using the z-score (number of standard deviations the raw value of the KPI was above the RV) as a parameter of the NORMDIST function of Microsoft Excel to give the probability of any other RV being below that RV, which was then multiplied by 100% to give a %ES. Essentially the %ES was the percentage of performances where a KPI value was lower than the observed value in matches of the same RQ (O'Donoghue & Cullinane, 2011).

### *2.4 Statistical Analysis*

The aforementioned procedures assume that the data was parametric and normally distributed. Based on the sample of 106 team performances a Kolmogorov-Smirnov test produced normally distributed data ($p>0.05$) for over 51% of the variables (Appendix 7), allowing parametric testing to be conducted. However, due to the desire to achieve parametric all of the data producing zeros were not reported, although this reduced the sample size for certain KPIs, as a zero was recorded no event took place and was therefore removed from the study, in turn producing parametric data.

A repeated measure ANOVA was used to test for significant differences ($p<0.05$, O'Donoghue, 2012) between the percentages of goals scored to specific zones and types of shots. Tests showed that although sphericity was violated ($p>0.05$), the Greenhouse Geisser adjusted ANOVA was reported to reduce type 1 error and increase confidence in significant results (O'Donoghue, 2012). Furthermore the statistical test within SPSS accounted for post hoc, bonferroni adjusted results.

Reliability was also conducted on the data using Cooper, Hughes, O'Donoghue & Nevill (2007) method derived from analysis on a test-retest basis on two separate occasions. Inter (researcher and level 3 experienced analyst) and intra operator reliability was assessed through identifying point of agreement (PA) scores and reporting no significant bias between any of the measured variables ($p>0.05$) as well as confidence intervals of all PI observed lying above 90% PA±1, the criterion for the level of analyst tested within the study (Cooper et al., 2007) (Appendix 9 & 10).

## 3. Results

The results of the study initially identified the breakdown of where goals where scored. Figure 3 and 4 show the breakdown of goals scored in all of the matches analysed. A significantly higher percentage ($F=27.429$, $p<0.001$) of goals were scored at zones 3 (25.06%) and 5 (33.72%) (pockets) than any other zone (Appendix 18). Further, figure 4 showed there was a significant difference between the type of shots ($F=184.208$, $p<0.0091$), that observed a higher percentage of goals were scored using the smooth shot than any other method (Appendix 18).

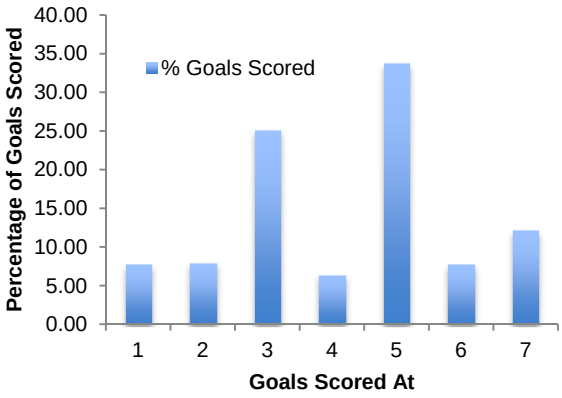


Figure 3. Percentage of goals scored to which zone.

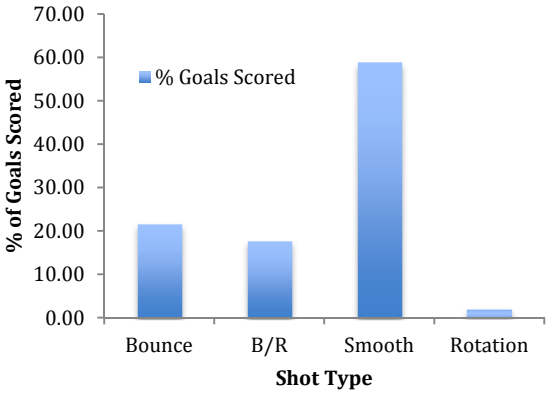


Figure 4. Percentage of goals scored with type of shot.

The regression-based analysis results showed that there was a weak positive correlation between the number of goals scored and RQ ($r =0.24$) as shown in figure 5. The line of best-fit shows that as the RQ of the team increased the team scored significantly more goals ($F = 6.105$, $p<0.05$).

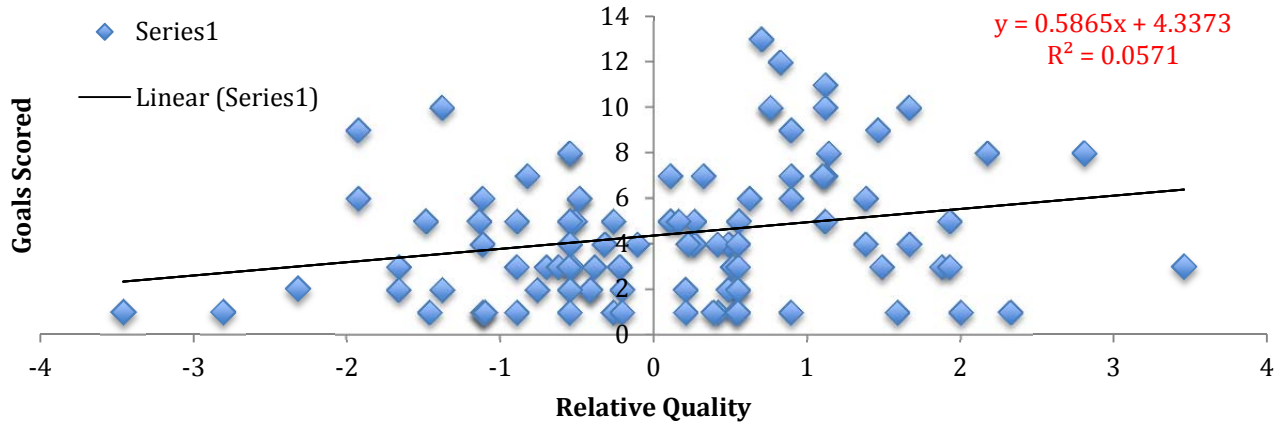


Figure 5. Scatter plot depicting the relationship between goals scored and RQ

Similarly goals conceded produced a weak negative correlation (R= -0.20) showing that as the RQ of the team increase, significantly fewer goals were conceded (F=4.187, p <0.05).

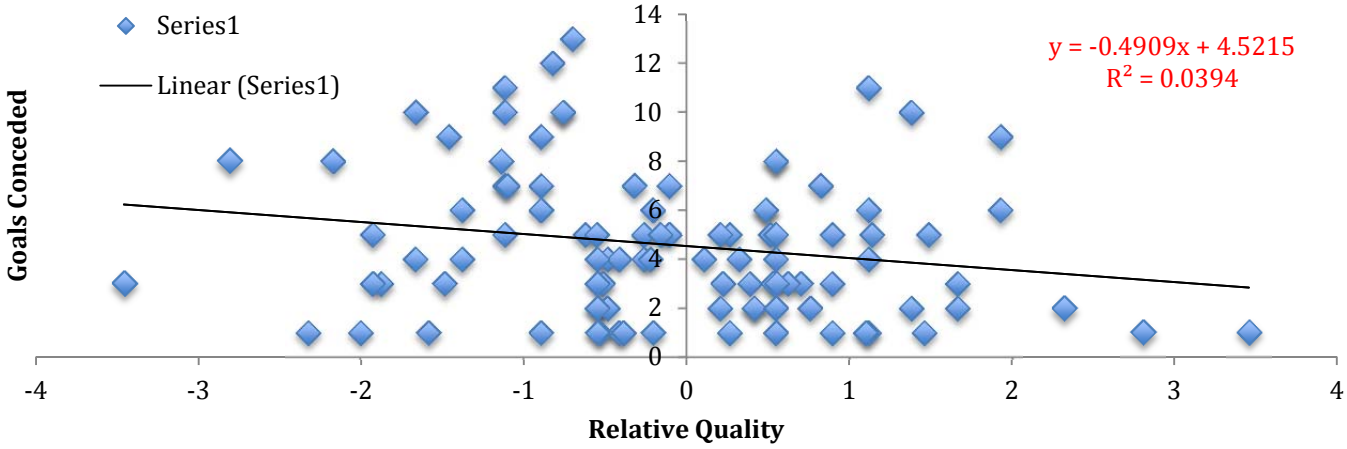


Figure 6. Scatter plot depicting the relationship between goals conceded and RQ.

In relation to the direction of the shot (Table 1) there was a weak, positive correlation between RQ and shots to the pockets with a trend (r=0.19, F=3.820, p=0.053), and significant difference for the speed of shot (F=4.048, p<0.05).

Table 1. Correlation and Significance of KPI and Regression.

| KPI | r value | $r^2$ | Correlation | Beta Value | Significance (p value) |
|---|---|---|---|---|---|
| Number of Shots | 0.03 | 0.001 | No | 0.151 | 0.78 |
| Shots to Pockets (%) | 0.19 | 0.35 | Weak +ve | 0.938 | 0.05 |
| Shots to Line (%) | -0.21 | 0.043 | Weak -ve | -0.779 | 0.03 |
| Shots to Player (%) | 0.05 | 0.002 | No | 0.203 | 0.62 |
| Shots Out (%) | -0.07 | 0.006 | No | -0.317 | 0.45 |
| Bounce Shots (%) | 0.03 | 0.001 | No | 0.449 | 0.76 |
| B/R Shots (%) | 0.17 | 0.028 | Weak +ve | 2.908 | 0.13 |
| Rotation Shots (%) | 0.08 | 0.007 | No | 0.278 | 0.60 |
| Smooth Shots (%) | 0.27 | 0.051 | Weak -ve | -4.491 | 0.02 |
| Speed of shot (kph) | 0.26 | 0.065 | Weak +ve | 0.592 | 0.05 |

Figure 7 showed the weak positive correlation between shots to pockets (%) and RQ, portraying that the stronger teams of such RQ made more use of shots to this area. When looking at earlier mentioned findings surrounding goals scored it was evidenced that more goals were scored to zones 3 and 5 (the pockets), implying increased accuracy and quantity of shots to this area was advantageous.

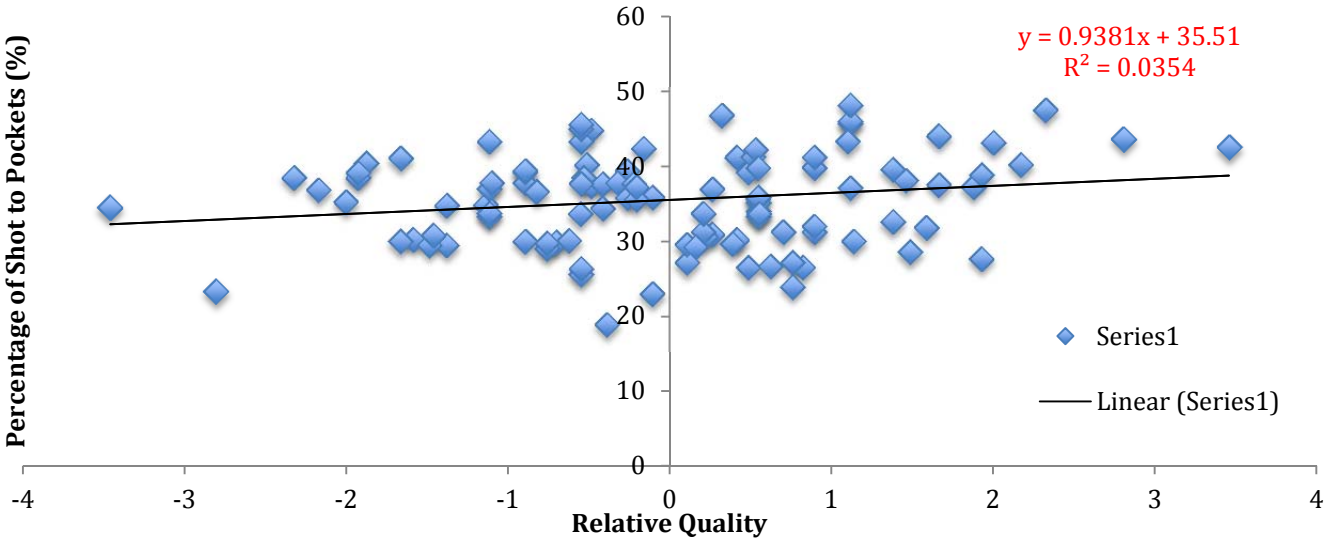


Figure 7. Scatter plot depicting the relationship between shots to pockets and RQ.

In contrast there was no correlation observed between two of the four shot types (rotation and bounce) and relative quality (table 1). Therefore showing that despite an increase in RQ the shot type was not affected, although there was a weak positive correlation (r=0.17, F=2.388, p>0.05) for the B/R shot (Figure 8).

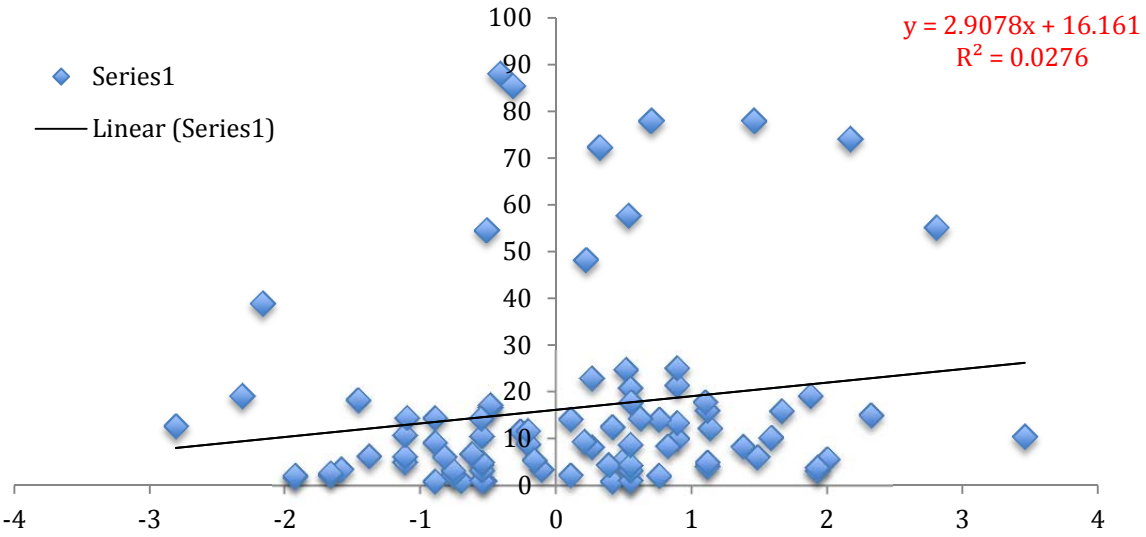


Figure 8. Scatter plot depicting the relationship between B/R shots and RQ.

### 3.1 Prediction Equation

In terms of application, a regression equation was produced from the slope and intercept of the data to give a predicted value for a KPI based on the RQ of the two teams (y+(x*RQ)). Using this equation, plus or minus the standard error estimate (calculated from the regression in SPSS) a value plus a range could be predicted for KPI. Further, the standard error estimate was calculated as a percentage to show the accuracy of the equation, with an accepted value of below 5% to provide 95% accuracy (McHugh, 2008) (Table 2).

Table 2 showed that only one of the KPI produced acceptable standard error estimates (Number of Shots) and two trends (Shots to Pockets and Players).

Table 2. Standard error and percentage of intercept

| Key Performance Indicator | Standard Error Estimate | Percentage of Intercept |
|---|---|---|
| Goals Scored | 2.9 | 66.86 |
| Goals Conceded | 2.9 | 64.14 |
| Number of Shots | 6.7 | 7.17 |
| Penalties Scored | 0.8 | 54.77 |
| Penalties Missed | 0.7 | 47.14 |
| Shots to Pockets (%) | 6.0 | 16.90 |
| Shots to Line (%) | 4.5 | 32.62 |
| Shots to Player (%) | 5.2 | 13.34 |
| Shots Out (%) | 5.2 | 44.61 |
| Bounce Shots (%) | 17.3 | 77.95 |
| Rotation Shots (%) | 3.9 | 91.99 |
| Bounce-Rotation (%) | 20.8 | 128.71 |
| Smooth Shots (%) | 23.8 | 37.27 |
| Speed of Shot (kph) | 2.9 | 8.93 |

### 3.2 Case Study

In order to explain the applied use of regression equation in Women's elite goalball a case study (O'Donoghue & Cullinane, 2011) was devised based on the performance of the GB team. Consider a performance between GB (rank 13) and Russia (rank 6) producing a RQ of -1.12. Using the regression equation it was then possible to predict values of KPI relating to the performance and thus compare the values to those achieved.

Table 3 evaluates the individual performance of the two teams in relation to performances against that RQ. For example against an opponent when GB's

RQ was -1.12 they would be expected to score 3.68 goals per game, thus in this instance the performance exceeded that of 79.11% of teams with the RQ of -1.12. Despite that, the performance was a losing one for GB as they conceded more than 74.67% of teams with a similar RQ value. Further, in relation to shots to pockets (area most likely to score goals, figure 3) Russia achieved 46% of their shots, 9.44% higher than expected and 94.36% more than other teams with an RQ of 1.12. Similarly, GB appeared to be over reliant on the smooth shot (95%, 26.13% higher than expected) in contrast to Russia who were only 36.94% higher in an unfavourable aspect of performance, instead using more bounce shots (70.63%) compared to other nations. Likewise Russia achieved a greater shot speed than expected (35.37kph), which was greater than 81.30% of other teams with an RQ of 1.12 in another favourable aspect of performance.

Table 3. Case study of GB v Russia with selected KPI.

**GB**

| KPI | Achieved | Predicted | Residuals (Difference) | Evaluation Score (%) | Upper Estimate | Lower Estimate |
|---|---|---|---|---|---|---|
| Goals Scored | 6 | 3.68 | 2.32 | 79.11 | 6.58 | 0.78 |
| Goals Conceded | 7 | 5.07 | 1.93 | 74.67 | 7.97 | 1.62 |
| Number of Shots | 100 | 93.24 | 6.76 | 84.63 | 99.94 | 86.54 |
| % Shots to Pockets | 37 | 34.46 | 2.54 | 66.49 | 40.46 | 28.46 |
| % Shots to Player | 34 | 38.75 | -4.75 | 17.67 | 43.95 | 33.55 |
| % Bounce Shots | N/a | N/a | N/a | N/a | N/a | N/a |
| % Smooth Shots | 95 | 68.87 | 26.13 | 86.63 | 92.69 | 45.09 |
| Speed of shot (kph) | 29.88 | 31.45 | -1.57 | 28.74 | 55.25 | 7.65 |

**Russia**

| KPI | Achieved | Predicted | Residuals (Difference) | Evaluation Score | Upper Estimate | Lower Estimate |
|---|---|---|---|---|---|---|
| Goals Scored | 7 | 4.99 | 0.01 | 50.12 | 7.89 | 1.44 |
| Goals Conceded | 6 | 3.97 | 2.03 | 75.70 | 6.87 | 1.07 |
| Number of Shots | 100 | 93.57 | 6.43 | 83.39 | 100.11 | 86.87 |
| % Shots to Pockets | 46 | 36.56 | 9.44 | 94.36 | 42.56 | 30.56 |
| % Shots to Player | 41 | 39.20 | 1.80 | 63.75 | 44.40 | 34.00 |
| % Bounce Shots | 32 | 22.69 | 9.31 | 70.63 | 39.99 | 5.39 |
| % Smooth Shots | 51 | 58.85 | -7.85 | 36.94 | 82.63 | 35.03 |
| Speed of Shot (kph) | 35.37 | 32.88 | 2.49 | 81.30 | 56.68 | 9.08 |

## 4. Discussion

The initial aim of the study was to identify where goals were scored and the consequent impact on success. The results showed that significantly more ($F=27.429$, $P<0.001$) goals were scored to the pockets, zone 3 (25.06%) and zone 5 (33.72%). This was a contemporary finding in relation to goalball research as previously Amorim et al. (2010) had only stated that more shots were directed toward the right and left side of the court than the centre. Developing further from the findings of the previous research, the results showed specifically the areas that goals were being scored. Furthermore regression-based analysis showed that there was a weak positive correlation (table 1) between RQ and shots to the pockets. This suggested that teams of higher RQ were more accurate shooting to the areas that scored a higher percentage of goals. In relation to the applied implications it was plausible to suggest that weaker teams should focus on improving accuracy to the pockets.

With regards to the aim of how goals were scored, the findings were similar to that of Lehto et al. (2012) in the fact that a similar proportion of goals were scored from smooth (58.78% v 62.60%) and bounce shots (21.55% v 21.20%). Contrast was found as Lehto et al. (2012) in that 16.20% of goals were scored from curved shots, compared to goals scored from B/R shots (17.56%) in the present study. This was further consolidated in relation to regression of shot type, as although only a weak positive correlation (table 1) was produced for the B/R shot ($r=0.17$) there were several outliers towards the right side of the scatter plot (Figure 8). Highlighting the tactical use of two

specific high RQ teams (Turkey and Israel) that achieved success through this approach. In comparison, the regression of the smooth shot produced a weak negative correlation, finding that teams of stronger RQ used the shot significantly less frequently ($F=5.598$, $p<0.05$). Therefore more contextual information was provided about the performance than previously available (Lehto et al., 2012) through the inclusion of opposition quality. The implied implication was that more variety was required for lower RQ teams. For example the GB women's team averaged 83.36% of smooth shots in comparison to Canada (Ranked 1$^{st}$) who averaged 25.66% (appendix 17). Therefore it could be suggested that the GB team should attempt to reduce the frequency with which they utilised the smooth shot, as teams of higher RQ achieved success through shots such as the bounce or B/R.

Due to the effectiveness of the B/R shot described by Bowerman et al. (2011) with regards to the increased velocity compared to the smooth shot (26m.s$^{-1}$ v 21m.s$^{-1}$), the omission of the B/R shot was a limiting factor of previous research (Amorim et al., 2010; Lehto et al., 2010; Lehto et al., 2012). Furthermore a weak positive correlation ($r=0.28$) was produced for the speed of shot with significantly faster speeds for higher RQ teams ($F=4.048$, $p<0.05$). Thus, implying that the higher RQ team produced greater velocity. Furthermore, when looking at the case study Russia produced an average speed of 35.37kph (RQ 1.12). The ES portrayed that the speed was greater than 81.30% of performances with an RQ of 1.12, ultimately highlighting the importance of generating a greater amount of velocity in the shot.

In terms of identifying whether there was a RQ effect for KPI in goalball the level of correlation produced for all KPI was low. However, despite O'Donoghue and Cullinane reporting values with no meaningful correlation, a practical application was still presented, as the findings were still meaningful. Another limiting factor of the regression-based analysis was the level of variation reported in table two and three. Table two showed that the percentage of the intercept reported for the regression was high, (>5%, McHugh, 2008). Furthermore table three highlighted the high level of variability between the upper and lower estimates of the prediction equation; again this suggested that caution should be applied when presenting results (O'Donoghue, 2012). However, such fluctuations could be attributed to the match-to-match variation that was experienced within goalball, as well as other team sports, as McGarry and Franks (1994) stated there is variability in sports performance, with the largest source of variability being opposition, which will always present in team sports.

A further limitation identified within the study was the use of goalball world rankings. This was due to the potential inaccuracies, specifically the ranking of certain nations influencing regression. For example Ukraine, a team finishing in the quarterfinals of the World Championships in 2014, were ranked 19$^{th}$ out of 28 nations. In contrast Sweden, were ranked 5$^{th}$ in the world despite being relegated to the European B tournament from the European A championships in 2013. Examples of such discrepancies were countless within the ranking system and therefore the validity was questionable. A more accurate ranking system would have benefited the

research, such as the ELO ranking system used in chess where each team was assigned the same arbitrary point score and points are awarded/subtracted after the result in relation to the overall standing of the team (Hvattum & Arntzen, 2010). This could have improved the correlation between RQ and KPI based on more reflective ranking system.

The implications of the study should therefore be viewed with caution, due to the potential limitations. However, the case study provided the potential applied use of the regression-based approach within goalball. As table three allowed the results of the study to attribute aspects of performance to success. The ES score presented the percentage of performances that the team exceeded against opponents of that RQ (Table 3, RQ ±1.12). For example, the table showed that GB needed to score between 0.78 and 6.58 goals to beat a team with an RQ of -1.12, where as Russia needed to score between 1.44 and 7.89 goals to beat a team with an RQ +1.12. The example presented the upper estimates of the equation with Russia winning 7-6. However, further detail showed that Russia exceeded the performance of other teams (against an RQ of 1.12) in desirable aspects of performance such as; shots to pockets (94.36%), speed of shot (81.30%) and bounce shots (70.63%). However, the GB team only exceeded the performance of 66.49% for shots to pockets and 28.47% speed of shot for an RQ of -1.12. This therefore portrayed an example where aspects of performance were identified to aid in the process of identifying successful performance in goalball.

Overall the regression based approach to analysing elite women's goalball, in similar respect to findings in tennis (O'Donoghue & Cullinane, 2011), evidenced that there was a low RQ effect for KPI in goalball. However, the inclusion of the upper and lower estimates, an aspect not included in the work of O'Donoghue and Cullinane (2011) allowed the results to account for the variability of sports performance. As criticised in previous research of PA (Mackenzie & Cushion, 2013) a lack of contextual information has restricted the findings. However, the main advantage of the use of the regression-based analysis, a development from the previous attempts to account for opposition quality (O'Donoghue, 2006; O'Donoghue, 2008; O'Donoghue et al., 2008; Cullinane, 2011) allowed greater understanding of the strengths and weaknesses of the opposition to be accounted for when assessing team sports performance (O'Donghue & Cullinane, 2011). Thus providing greater context about the performance in goalball. Further the study provided a development on the level of understanding available in goalball and the impact of KPI in relation to performance, specifically confirming the conclusions of Lehto et al. (2012) that fast, accurate shots were desirable to successful performance, through the identification of KPI such as shots to pockets, speed of shot and variety of shots (such as B/R and bounce shots) lead to successful performance in goalball.

Future development of the work could incorporate a valid ranking system, such as the ELO ranking method (Hvattum & Arntzen, 2010) to further develop the use of regression to understand goalball performance. Furthermore, the impact of defensive actions could be assessed as the results

were focused specifically on the offensive actions within the study. Also the research of the physiological aspects of performance that can attribute to success performance would benefit the research, as previous research had stated that fatigue was reached in goalball (Silva et al. 2010), yet there was no physiological evidence to suggest whether fatigue had been present or whether a level of fitness was required to produce successful goalball performance.

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**Appendix List**

All appendices are stored on the disc provided and all match footage is stored on a hard drive by the researcher and is available upon request.