Determining optimal shot selection strategy in Super Netball's 'Power 5' period via numerical simulation

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Abstract

Insert abstract…

TODO:

- Check consistency of Super Shot vs. Power 5 period (use Power 5 period)
- Look to ESSA abstract for some sample points and language
- Add line spacing between paragraphs

Introduction

Netball is a court-based team sport played predominantly among Commonwealth nations, and has one of the highest participation rates for team sports in Australia (**AustralianSportsCommission2020?**). As in many court-based team sports, the goal of netball is to score more than the opposition. Netball is, however, unique in that goals may only be scored by two players on each team from within the 'shooting circle' (i.e. a half circle around the goal with a 4.9m radius) at their end of the court (**INFrules?**). Traditionally, goals scored from within this circle result in one goal for the team (**INFrules?**). In the 2020 season, Australia's national elite-level league (i.e. Suncorp Super Netball) made the decision to introduce the 'Super Shot' (**NetballAusSuperShotIntro?**). The Power 5 provided teams an opportunity to gain one- versus two-goals for successful shots made from the 'inner' (i.e. 0m-3.0m) versus 'outer' (i.e. 3.0m-4.9m) circles, respectively, within the final five minutes of each quarter (i.e. the Power 5 period) (**NetballAusSuperShotIntro?**). The rule has remained in place over subsequent seasons since the 2020 inception.

Our analysis prior to the 2020 season (**Fox2020?**) suggested that the added value of the Super Shot (i.e. two-goals) aligned well with the elevated risk of shooting from long range, and that teams may have been able to maximise their scoring by taking a high proportion of Super Shots. These findings were, however, based on shooting statistics from a past season where the Super Shot rule was not in effect. Further investigation of netball competitions where a 'two-goal rule' was in place (i.e. international Fast5) resulted in a much higher risk of missing long-range shots (**Fox2020?**). We hypothesised that the elevated risk of missing long-range shots with a 'two-goal rule' in place stems from situational factors, whereby defensive strategies were likely altered to place a heavier emphasis on defending long-range shots (**Fox2020?**). Data from the early years of the Super Shot in place provides an opportunity to re-evaluate the risk:reward value of taking Super Shots with more valid shooting statistics. Further, these data can provide a better foundation for simulating Power 5 periods as a means to identify optimal shooting strategies. In the present study, we first ran simulations of the Power 5 period for each team individually in an attempt to identify expected scoring outcomes stemming from different Super Shot selection strategies. Second, we ran simulations of teams competing against one another during a Power 5 period to determine how varying the Super Shot selection strategy could impact scoring margin.

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Methods

Participants

Participants for this study included all players across the eight teams from the 2020-2022 seasons season of the Australian national netball league (i.e. Suncorp Super Netball). Our study included publicly available, pre-existing data held on the Suncorp Super Netball Match Centre. An exemption from ethics review was granted by the Deakin University Human Research Ethics Committee (***TODO: add details***).

Data Collection

We used the *{SuperNetballR}* (***TODO: citation***) package to extract match data from all regular season games during the 2020-2022 Super Netball Seasons via the Champion Data (official provider of competition statistics) Match Centre. All shots are labelled with identifiers that place them in the inner or outer circle, along with whether they were made or missed. Combined with the timestamp of these events within quarters, we extracted team-specific shooting statistics for: (i) the total number of shots taken; (ii) the number of shots taken from the inner and outer circle; and (iii) the number of made and missed shots from the inner and outer circle from each Power 5 period across matches.

Data Analysis

Our study required estimating the probability of making versus missing shots from the inner versus outer circle across the different teams. We achieved this by defining a beta distribution in a probability density function for the different circle zones, specified by:

$$f(x, a, b) = \frac{\Gamma(a+b)x^{a-1}(1-x)^{b-1}}{\Gamma(a)\Gamma(b)}$$

where a and b represent the number of missed and made shots within a circle zone, respectively; x is the probability of a relative to b; and Γ is the gamma function (**NIST2020?**). Probability density functions were created for made versus missed shots in the inner and outer circles for each team to be used in subsequent simulations.

First — we ran a series of simulations (n = 1,000 each) of the Power 5 period for each team, altering the 'tendency' for each shot to be taken as a Super Shot. Across each individual simulation, the total number of shots the team received was driven by their expected number of shots in a Power 5 period based on the three seasons worth of data. Specifically, the mean and standard deviation (SD) of shots a team took during Power 5 periods was used to create a truncated normal distribution (upper and lower limits set at ±95% confidence intervals [CIs]) — of which the number of shots for a team in an individual simulation were randomly sampled from. Within each simulation, whether an individual shot was taken as a standard or Super Shot was dictated by the current tendency being simulated. We repeated each simulation across five tendencies towards taking Super Shots, those being: (i) 'zero' (0% chance of Super Shot being taken); (ii) 'low' (25% chance of Super Shot being taken); (iii) 'moderate' (50% chance of Super Shot being taken); (iv) 'high' (75% chance of Super Shot being taken); and (v) 'all out' (100% chance of Super Shot being taken). For each individual shot during the simulation, a random number between zero and one was generated from a uniform distribution — and a Super versus standard shot was taken depending on if this was lower versus higher, respectively, than the chance of taking a Super Shot (e.g. a random value of 0.45 within a 'high' tendency simulation would result in a Super Shot being taken). The success (i.e. make vs. miss) of each individual standard or Super Shot within the simulation was then determined by generating a random value between zero and one from a uniform distribution, alongside a value sampled from the teams relevant probability density function of making a shot from the relevant location (i.e. inner or outer circle). If the value sampled from the probability density function was greater versus lower than the random value — the shot was considered successful versus unsuccessful, respectively. After all individual shots were simulated, the total team score was summed given the value of the made standard and Super shots. We calculated the scores achieved with the varying Super Shot tendencies relative to the 'zero' tendency (mean ± SD, range) to examine the expected increase or decrease in scoring with altered Super Shot selection strategies.

A similar approach was taken in simulating teams competing against one another during Power 5 periods. A series of simulations (n = 1,000) of Power 5 periods were ran between all combinations of teams. We

Table 1: Shot frequencies by team across 2020 — 2022 seasons used to create probability density functions for use in simulations.

Team	Standard Goal	Standard Miss	Super Shot Goal	Super Shot Miss
Fever	783	24	168	159
Firebirds	622	87	179	207
GIANTS	409	37	315	254
Lightning	634	68	162	152
Magpies	590	47	159	140
Swifts	545	62	201	176
Thunderbirds	527	48	167	170
Vixens	527	60	194	176

once again used the probabilities of making versus missing shots from within and outside the outer circle during the Power 5 period from each team to estimate scoring. To determine the number of shots each team received in a simulation, we created two truncated normal distributions based on the mean and SD of total shots of total shots and the proportion of shots by teams in Power 5 periods (upper and lower limits set at minimum and maximum values). The number of shots the first team received (i.e. Team A) was determined by the product of values randomly sampled from the two distributions (e.g. values of 12 and 0.75 would result in 9 shots to Team A) distribution of total shots. The number of shots the second team received (i.e. Team B) was then determined by allocating those remaining from the total shots (e.g. in the aforementioned example Team B would receive the remaining 3 shots). As part of this approach we ensured that there was an appropriate balance between the disparity if shots each team received (i.e. each team received an even amount of simulations where they had the same amount of more vs. less shots). The series of 1,000 simulations was repeatedly ran between all combinations of teams and the aforementioned Super Shot selection tendencies. Standard versus Super Shot selection and shot success within simulations were determined in the same manner described earlier (i.e. random number generator vs. chance of Super Shot being taken and value sampled from the teams shot success probability distribution). At the end of each simulation, the teams scores were summed and the subsequent margin determined. The mean ± SD and range for margins between each team across the various Super Shot tendency combinations were then calculated. We also inspected the proportion of simulations each team won versus lost across simulations and the mean ± SD margin in these cases.

Results

The shot frequencies for each team used to create probability density functions for use in simulations are displayed in Table 1.

Our initial simulations of individual team scoring within Power 5 periods using variable Super Shot selection tendencies found a small increase in mean scoring relative to the 'zero' Super Shot tendency. Across all teams, the mean (± SD) goals scored relative to the 'zero' tendency was 1.03 (± 0.21), 1.07 (± 0.30), 1.10 (± 0.37) and 1.14 (± 0.43) across the 'low,' 'moderate,' 'high' and 'all out' strategies, respectively. Alongside the mean increase in relative goals scored, we observed a corresponding widening of the variance (i.e. SD) and range of scoring values (i.e. range) with higher tendencies to take Super Shots — with these observations consistent across teams (see Figure 1).

Our simulations of Power 5 periods between teams revealed that on average the margins between the two teams remained closed to zero irrespective of the Super Shot tendency used or team involved (see Figure 2). We observed larger vs. smaller maximal margins in simulation conditions where higher versus lower Super Shot tendencies were simulated, respectively (see Figure 2).

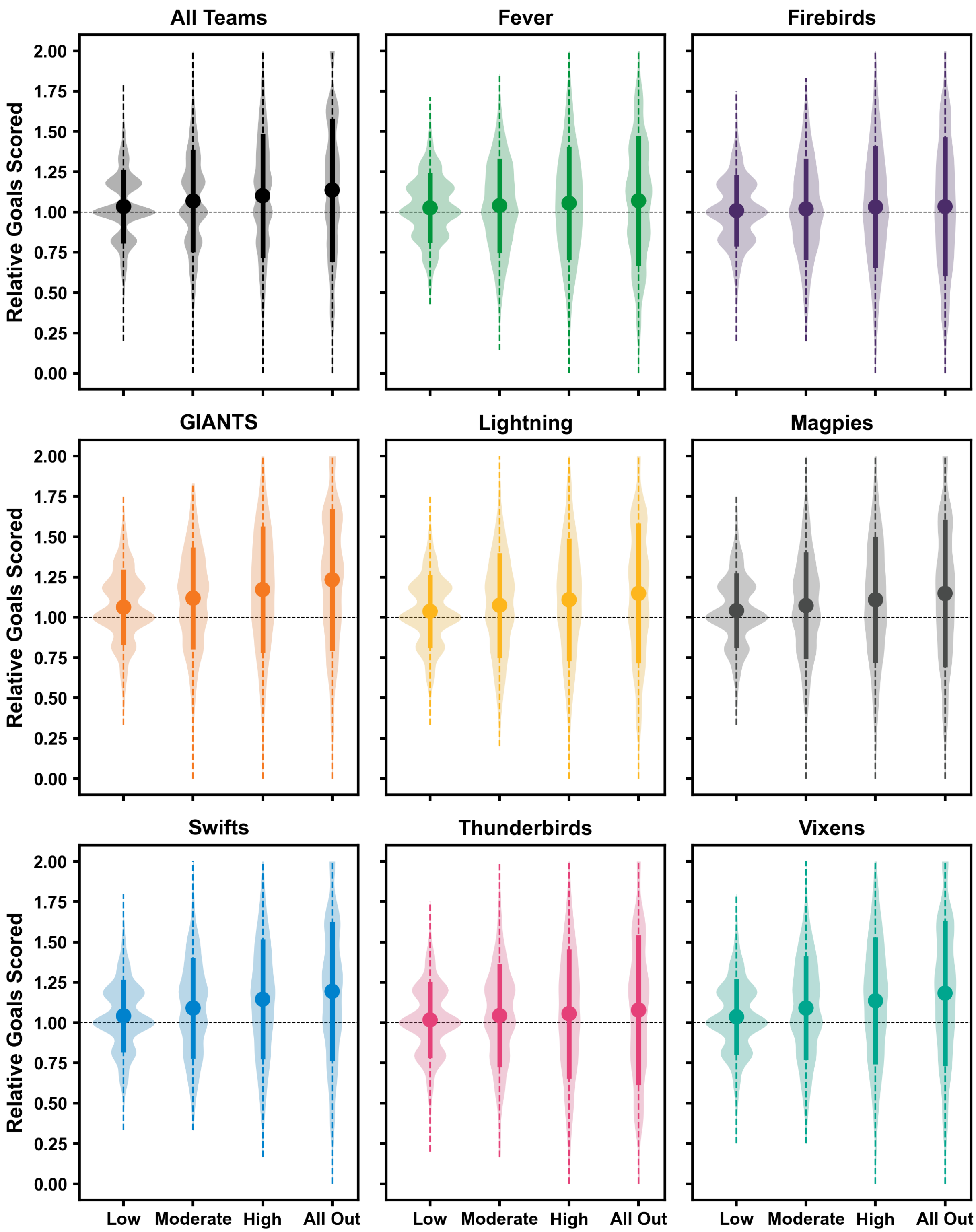

Figure 1: Total goals scored by teams across simulations (n = 1,000) with different Super Shot selection tendencies relative to the 'zero' Super Shot tendency. Point and solid lines represent mean ± standard deviation. Dashed line represents range of data. Shaded violin represents distribution of data.

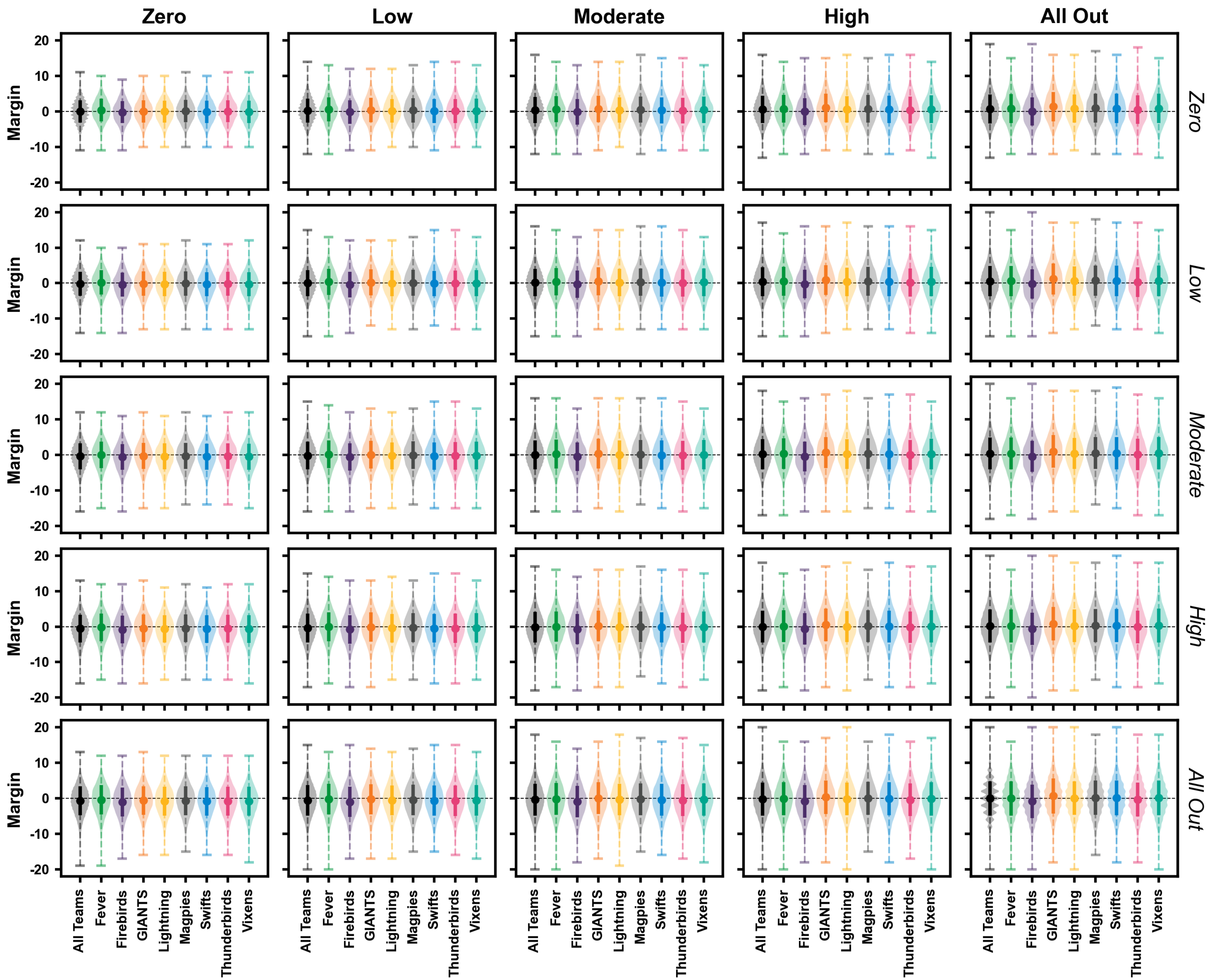

Figure 2: Power 5 period margin between teams during simulations (n = 1,000 using different Super Shot tendencies. Positive and negative margings reflect the period being won

Supplementary figures…

Discussion

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- Teams can score more with higher super shot tendencies, but also a lot less - larger ranges
- In competitive sims, on average across large number of simulations things end up pretty even – But there are some relatively clear floors and ceilings depending on strategies — (e.g. zero tendency vs. all out, can't beat by as much as other strategies, and can also lose by a lot more)
- While there weren't large fluctuations, certain teams had a better probability of winning a power 5 period with different strategies
- Situational when to use
- Conclusion - on average, it doesn't matter, but selection of Super Shot strategy likely needs to consider the situation, your teams skillset, and your opponents strategy

…

Our analysis of shot statistics from the first season of the Super Shot demonstrated an approximate four-times higher likelihood of missing from the outer versus inner circle, irrespective of the match period (i.e. standard vs. Super Shot period). While the 95% CIs did overlap between the two periods, a slightly higher risk of missing from the outer versus inner circle was present in the Super Shot period. Our present findings conflict with our earlier work from the 2018 Super Netball season where we observed an approximate two-times higher risk of missing from the outer versus inner circle — and suggested that the 2:1 point ratio of the Super Shot represented 'good' value relative to the elevated risk of missing (**Fox2020?**). Our present analysis perhaps suggests this is no longer the case — as the risk of missing from the outer circle has approximately doubled, and now outweighs the additional point value on offer. Across the different teams and periods, We found in all but one instance that the risk of missing from the outer versus inner circle was greater than two-times that of the inner circle. The only instance where the 95% CIs overlapped the 2:1 ratio was for the Firebirds during the standard period. This specific case is irrelevant, however, as the additional points were not available during this time. The obvious difference between the present study and our previous work (**Fox2020?**) is the actual presence of the Super Shot being on offer during the 2020 season. The elevated risk of missing from the outer versus inner circle from the 2018 to 2020 Super Netball season is similar to what we observed in originally comparing the 2018 Super Netball to Fast5 (i.e. where long range shots were also rewarded with additional points) (**Fox2020?**). Therefore, it seems apparent that adding value to long-range shots in netball induces an adjustment in the way either attacking and/or defensive teams play that elevates the risk of missing long- versus close-range shots. There are a number of factors that could be contributing to this elevated risk. The most likely reason is an additional emphasis from defensive players on preventing or contesting long-range shots given their added value. This may also have an inverse effect on the difficulty of generating and taking standard shot opportunities, where by virtue of defensive strategies focusing on Super Shots could make it simpler for teams to get easier shots closer to the post. The presence of the Super Shot may also introduce psychological pressure on the shooting player and influence the chance of success. A more thorough analysis of defensive strategies and understanding shooting players perspectives around the Super Shot can assist in understanding the mechanisms behind any elevated risks of missing long-range shots with added rewards.

Despite the Super Shot potentially holding an unbalanced risk-reward trade-off (in general), there are likely scenarios where it is an attractive option or appropriate risk. When trailing by a large margin with minimal time remaining, the one point on offer for a standard shot may present very little value to the trailing team. In this scenario, the Super Shot potentially becomes the only or default option. Conversely, the leading team would likely adopt a 'safe' approach and minimise their Super Shot attempts. Our analysis also considered overall team shooting statistics. The relative risk of missing a Super Shot may change for an individual (i.e. specialist) long-range shooter. If a team possesses such a player, emphasising Super Shots could represent a relatively valuable opportunity. Similarly, there is some evidence to support the 'hot-hand' premise in shooting sports (**Bar-Eli2006?**). A team may benefit from preferentially feeding a shooter possessing this characteristic for Super Shot attempts during a Power 5 period.

Restricting Super Shot attempts appears to be a safe, but likely limiting strategy for scoring during Power 5 periods. Our simulations examining potential scoring outputs with varying Super Shot proportions demonstrates this premise. Employing a low proportion (i.e. $< 30\%$) of Super Shots resulted in relatively low to moderate, but consistent, scoring outputs. The high probability of standard shot success is the likely driving factor behind the consistent scoring with lower Super Shot proportions (i.e. higher standard shot proportions). Conversely, a high proportion (i.e. $> 80\%$) of Super Shots resulted in a much wider spectrum of scoring outputs from relatively low through to high. Increasing the proportion of Super Shots taken generated a progressive increase in the maximum score achievable (i.e. higher ceiling), but also coincided with a decrease in the minimum score achievable (i.e. decreased floor). Teams taking a high proportion of Super Shots during Power 5 periods likely expose themselves to volatile scoring outcomes — effectively 'living or dying by the sword' that is the Super Shot. ***Anything to wrap-up this point?***

Competitive simulation discussion paragraphs…

Examining the 'typical' margins within the simulated Power 5 periods (i.e. mean ± 95% CIs) between teams revealed that, irrespective of the strategies used, the margins were typically low – rarely exceeding 1.5 to 2 points (see **??**). There were times across the simulations were higher margins were present (***TODO: refer to supplementary figures***), yet these were rarer occurrences. These data suggest that optimising the proportion of Super Shots taken versus allowing by a team and their opponent, respectively, can yield small but potentially meaningful benefits. A yield of one to two goals across each quarter would equate to four to eight goals across an entire match. Given netball matches can often be decided by a small number of goals – this may present a significant advantage for a team. There is, however, a degree of variability across these results and teams would not be able to expect the same outcome every time a specific strategy is employed. This would likely be more evident with respect to strategies employing a high propotion of Super Shots. As identified in our earlier analyses, a higher proportion of Super Shots introduces a degree of volatility in a teams scoring output – and hence has the same potential to introduce volatility in the margin the team would encounter during such Power 5 periods.

…high proportion of Super Shots may yield a beneficial result on average for a team, but given the approach being taken there will likely be times where this could backfire on the team…

The optimal proportion of Super Shots to take versus allow likely varies from team to team. For example, …

…also other factors to consider that may dictate success…number of shots…shooting percentage… For example, generating a greater number of shot opportunities than your opponent will likely lead to better scoring and margins - and may also provide a greater scope to risk taking a greater number of Super Shots… …investigating these additional factors…outside the scope of this investigation…

Looking at the margin summaries (mean +/- 95% CI's) from each teams competitive simulations across all opponents, certain strategies appeared more or less favourable across different teams. For example, where the Fever extended above 50% of their shots as Super Shots, it was typical for them to score less than their opponent in the Super Shot period; whereas when they used no Super Shots they typically outscored their opponents. Other trends…?

Remaining discussion points…

Our approach in the present paper to simulate Super Shot scoring periods differs to our original work (**Fox2020?**). Previously, we allocated an overall success rate to shots from the inner versus outer circle (i.e. if the sampled probability was 50%, a total of 50% of shots were counted as successful). This contrasts to our present work, where we sampled and applied the probability of shot success to simulated individual shots (i.e. if the sampled probability is 50%, the individual shot being simulated has a 50% probability of success). This approach likely reflects an improvement on our analysis, better representing the independent nature of shots in a netball match.

- Team specific values, any obvious differences? For example, one team may have had better success and therefore using a higher proportion in general may have led to higher percentage of 'won' periods
- Team vs. team specific values and if they are different across various opponents. For example, better shooting success with high super shot proportions vs. one team but not another? This may be more relevant if we use opponent specific probabilities of super shot success. Important that the lack of 'defensive' presence within simulations is acknowledged as a limitation, in that we applied the same super shot probability rates for each team from their entire season, rather than individually vs. their

oposition team. Given we might have some relative risk of missing against different defensive opponents, this may actually reveal that this should be a consideration if one team is more effective with their defense
- Practical considerations of work include strategising around super shot, with respect to how many to take perhaps depending on margin along with opposition, as well as own teams success in this realm

Discussion notes. . . check paragraphs here

Our simulation data does, however, demonstrate potential value in using the Super shot for certain teams and in certain scenarios. Times where higher proportion of super shot was valuable? We incorporated variable shot opportunity numbers based on league data, and hence the number of shot opportunities varied across individual simulations for teams. This was balanced, in that when teams received more shot opportunities, their opposition received fewer. Across all simulations, the wining team received more shots on x% of times. This factor became more/less evident across scenarios where a team took a higher proportion of super shots, whereby the winning team had more shots in x% of these simulations. This firstly suggests that generating more shot opportunities than your opponent is obviously beneficial, but potentially awards you more flexibility when considering taking a greater proportion of super shots.

Similarly, teams who were better with the Super shot fared better in simulations with greater proportions of super shots, and vice versa for teams that are worse. For example, the fever lost x% of simulations when they went heavy on the Super shot, vs. X team who won x% of simulations when using a high % proportion of super shots. This is not surprising as the fever had the highest risk of missing from the outer vs inner circle, particularly during Super shot periods. These findings likely demonstrate a need for teams to play to their shooting strengths.

Conclusion

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Scenario specific use. . .

Limitations - global probability of Super Shot success from teams across three seasons, unlikely to be representative of the exact shooting combinations that are put forward during a Power 5 period (e.g. emphasis may be given to specialist long distance shooter); independent probability approach whereby each individual shot was pitted against overall probability of success (i.e. ignores any sort of 'hot hand' effect); similarly, the tendencies simulated were all or nothing in a sense that in an 'All Out' strategy if the first couple of Super Shots missed the team might pull back, hence some simulations likely represented worst case outcomes that may not eventuate in such a circumstance

Bibliography styles

There are various bibliography styles available. You can select the style of your choice in the preamble of this document. These styles are Elsevier styles based on standard styles like Harvard and Vancouver. Please use BibTeX to generate your bibliography and include DOIs whenever available.

Here are two sample references: (Dirac, 1953; Feynman and Vernon Jr.; 1963).

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