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The Effect Touches, Post Touches, and Dribbles Have on Offense for Men's Division I Basketball

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THE EFFECT TOUCHES, POST TOUCHES, AND DRIBBLES HAVE ON OFFENSE FOR MEN'S DIVISION I BASKETBALL

by

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GRADUATE COMMITTEE APPROVAL

of a thesis submitted by

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This thesis has been read by each member of the following graduate committee and by majority vote has been found to be satisfactory.

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As chair of the candidate's graduate committee, I have read the thesis of Kim T. Jackson in its final form and have found that (1) its format, citations, and bibliographical style are consistent and acceptable and fulfill university and department style requirements; (2) its illustrative materials including figures, tables, and charts are in place; and (3) the final manuscript is satisfactory to the graduate committee and is ready for submission to the university library.

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ABSTRACT

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The purposes of this study were to evaluate the effects touches per play, post touches per play, and dribbles to end a play (DEP) have on points per play, field goal percentage, turnovers, and fouls. This was done to provide empirical evidence on anecdotal theories held by coaches concerning ball movement, dribbles, and post touches. The data collected were statistically analyzed using Bayesian hierarchical models. This study reports some intriguing trends. First, exceeding nine passes and three dribbles to end a play results in a decrease in points per play and field goal percentage. Second, up to three dribbles into a shot was more productive and efficient than shooting with no dribbles. Third, post play does not have as big an effect on offensive basketball as previously expected. Lastly, offensive rebounds seem to universally have a positive effect upon offensive basketball. This study supported some anecdotal beliefs about basketball, while not others, supporting the idea for statistically based studies to be conducted on anecdotal beliefs held about basketball.

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THE EFFECT TOUCHES, POST TOUCHES, AND DRIBBLES HAVE ON OFFENSE FOR MEN'S DIVISION I BASKETBALL

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Abstract

The purposes of this study were to evaluate the effects touches per play, post touches per play, and dribbles to end a play (DEP) have on points per play, field goal percentage, turnovers, and fouls. This was done to provide empirical evidence on anecdotal theories held by coaches concerning ball movement, dribbles, and post touches. The data collected were statistically analyzed using Bayesian hierarchical models. This study reports some intriguing trends. First, exceeding nine passes and three dribbles to end a play results in a decrease in points per play and field goal percentage. Second, up to three dribbles into a shot was more productive and efficient than shooting with no dribbles. Third, post play does not have as big an effect on offensive basketball as previously expected. Lastly, offensive rebounds seem to universally have a positive effect upon offensive basketball. This study supported some anecdotal beliefs about basketball, while not others, supporting the idea for statistically based studies to be conducted on anecdotal beliefs held about basketball.

Introduction

Basketball, which was created by James Naismith to better hold physical education students' attention during the winter months (Fox, 1974), has become a multi-billion dollar business at both the college and professional levels. In 1999 the Columbia Broadcasting Station (CBS) agreed to pay the National Collegiate Athletic Association (NCAA) $6 billion over 11 years for the television rights of their men's national basketball tournament starting in 2003 (Sandomir, 1999). The National Basketball Association (NBA) has received more lucrative television contracts than the NCAA, receiving a total of $6.6 billion from Turner Network Television (TNT), American Broadcasting Company (ABC), and Entertainment and Sports Programming Network (ESPN) to cover the NBA for six seasons, starting with the 2002-03 season (NBA, 2008).

The NCAA and NBA are not the only entities making money off the popularity of basketball. Individual teams, when successful, can also enjoy many financial benefits. In 2006 George Mason University made an unexpected run to the Final Four. According to the school, it received $677.5 million in free media during the 2006 tournament (Baker, 2008). In addition, since its Final Four appearance it has seen admission inquires increase 350%, donations to their athletic club increase 52%, and season ticket sales double for the following basketball season (Baker, 2008).

In the NBA, large television contracts and bigger arenas have made franchises worth more today than ever before (NBA, 2007b). With the exception of the New York Knicks all the teams who make up the top ten in the league in overall value have made the playoffs a minimum of two out of the last three seasons previous to this study (2005

NBA, 2005; 2006 NBA, 2006; 2007 NBA, 2007; NBA, 2007b). This suggests that the more a team wins, the more they will be worth. This motivates owners to pay players multi-million dollar contracts in hopes of compiling enough talent to win consistently. However, there are rules in both college and professional basketball limiting how much a player can be compensated for their services. This has left universities and franchises looking for additional ways to gain an advantage.

One way they have done this is through the hiring of head coaches. There is no limit on what coaches can be paid, therefore teams will often compete over those perceived as premier coaches and lure them to their team by offering them large salaries. In 2006, the average income for a coach making the NCAA Men's Basketball Tournament was $800 thousand per season. This amount rose to $1.2 million among coaches from the six Bowl Championship Series (BCS) conferences (Wieberg & Upton, 2007). In the NBA, the average coach makes $3.81 million per season and the highest paid coach for the 2007-08 season was Phil Jackson who made $10.33 million (Walker, 2007).

While universities and NBA franchises are paying coaches all-time high salaries, they expect almost instant returns from their investment. Therefore, if a coach does not win within their first three seasons, there is a high probability they will be looking for a new job (Berry, 2004). The impatience of university presidents and NBA team owners is evident by the number of coaches being fired annually. Following the 2006-07 season there were 62 Division I college basketball coaching changes among the 336 coaches (Division, 2007). In the NBA, 9 of the 30 coaches or nearly 33% lost their job (NBA,

2007a). With coaches being given less time to prove themselves to their bosses, they are constantly trying to identify factors that will give them a competitive advantage and help them win consistently.

A common way coaches have traditionally prepared their team for upcoming opponents is through the use of video. Coaches will watch game film of their own team, trying to look for deficiencies they can improve on during practice. They also watch game film on their opponents, identifying their strengths, weaknesses, and tendencies so that they can prepare a game plan that will give their team the best opportunity to win. With modern technologies such as video editing programs, DVD burners, and internet exchange systems, watching film has never been easier or more efficient. However, because basketball schedules typically require teams to play two to four games per week there is a limited amount of time a coach can devote to watching game film. This has left coaches looking for additional tools to evaluate their team and opponents in a quick and efficient manner.

One approach commonly used is quantitative analysis of box-score statistics. Box scores provide a summary of the game by listing important statistical categories for each player who participated in the contest. These categories typically include name of player, position of player, minutes played, makes and attempts for field goals, three pointers, and free throws, offensive rebounds, total rebounds, assists, turnovers, blocked shots, steals, personal fouls, and points. Looking at box scores at the conclusion of a game gives a coach a general sense of how his team performed in the different statistical categories.

However, if more than surface knowledge about a team is going to be acquired using box scores, it is necessary to use more sophisticated statistical analyses.

One such approach is the use of regression analysis. By analyzing box score statistics using regression analysis, studies have been able to determine which performance factors significantly contribute to the outcome of the game. Multiple studies have been conducted and they all conclude that field goal percentage is the strongest indicator of a team's win percentage (Akers, Wolff, & Buttross, 1991; Chatterjee, Campbell, & Wiseman, 1994; Onwuegbuzie, 2000). Additional findings from these studies (Akers et al., 1991; Chatterjee et al., 1994; Onwuegbuzie, 2000) support the philosophy of Dean Oliver (2004), who after statistically analyzing thousands of basketball games believes there are four critical aspects that a team must control both offensively and defensively to win the game. Those aspects are field goal percentage, offensive rebounds, turnovers, and free throws (getting to the foul line more often and making more foul shots than your opponent). Determining which performance indicators significantly contribute to the outcome of the game can aid a coach in analyzing a game by focusing his attention on areas which impact the game most. It also serves as a starting point for additional research to be done.

Although box-score statistics provide a nice summary of the game, they possess some limitations. First, basketball statistics in box scores do not always equate actual player value (Oliver, 2004). For example, a defensive player might deflect the ball causing it to fall in the hands of one of his teammates. The player that secures the ball is credited with a steal, when in all actuality it is the player with the deflection that played

the more outstanding defense and caused the steal. This is one example of many different situations throughout the course of a game where the box score does not give accurate value to the actual play or player.

Second, basketball statistics at the end of a game can be greatly influenced by the pace of play. In baseball, a game could take two hours or four hours to complete and it does not impact the statistical aspect of the game because there are equal outs for each team in every game and thus equal opportunities at success or failure (Oliver, 2004). In basketball this is not the case. For example, Team A might allow on average 75 points per game and Team B might allow 80 points per game. The normal observer might assume from the following information that Team A is a better defensive team than Team B because they allow five fewer points a game. However, when you look at a team's pace of play one might come to a different conclusion. In this same example Team A plays a slow-paced game and only averages 75 defensive possessions per game, while Team B plays a high-paced game and averages 100 defensive possessions per game. With this information you would conclude that Team B is the better defensive team because even though they allow more points per game than Team A, they do so on much more opportunities. Similar to points allowed per game, pace of play will impact all statistics found in box scores making it difficult to compare the information from game to game and team to team.

Being able to compare their team's performance from game to game and from opponent to opponent is a critical aspect of game analysis for a coach because it shows strengths, weaknesses, and trends that can be used to design a plan to improve.

Therefore, to make it easier to compare basketball statistics among teams, an equal possession concept has been implemented. In basketball statistics a possession starts when one team has control of the ball and ends when they lose control of the ball to their opponent following a made field goal, a made free throw, a defensive rebound, or a turnover. Thus, an offensive rebound will not start a new possession; instead, an offensive rebound starts a new play making it possible to have multiple plays within the same possession. This distinction is necessary to keep possessions during a game equal for both teams. Recording possessions in this way controls for pace and makes it easy to compare teams or individuals against each other (Kubatko, Oliver, Pelton, & Rosenbaum, 2007).

Analyzing box-score statistics using the equal possession concept enables coaches to gain greater insight into their team and players by performing efficiency analyses. Efficiency analyses measure a statistical aspect of basketball over 100 possessions, making it possible to determine how efficient a team or individual is in a certain aspect of the game. An example of how this analysis is used can be seen in offensive efficiency ratings. On television you will routinely hear commentators refer to a team's points per game to justify whether a team is good or bad on offense. For example, a commentator might say, "Team A scores 86 points per game, giving them the best offense in the league." This statement might or might not be true, but you cannot determine this from points per game alone because this statistic is affected by pace and only tells who scores the most points in the league. A better indication of how good a team is offensively is determined by offensive efficiency rating. This rating shows a team how many points

they score per 100 possessions. Using this value controls for pace and allows one to determine how efficient a team is at scoring. Knowing a team's offensive efficiency is more useful because it reflects how a team will perform independent of game pace and gives a better indication of offensive capabilities than points scored per game. (Kubatko et al., 2007).

Efficiency analysis can be done on all aspects of the game both offensively and defensively. This information can then be used by coaches to compare their team against all other teams in the league. Knowing how one's team compares to the rest of the league can reveal strengths and weaknesses and be valuable information when planning practices or setting team goals.

In addition to efficiency analyses, box-score statistics can also be used to do percentage analyses. Percentage analyses tell a coach what percentage of all possible opportunities their team performs a specific outcome. An example of how percentage analysis can be useful is seen in rebounding. The statistic rebounds per game can be misleading; a team might average a lot of offensive rebounds because they miss an unusual amount of shots. To get a better idea of how well your team offensive rebounds within a game, a coach would want to know how many of all possible offensive rebounding opportunities their team secured. This information is assessable by determining the team's offensive rebounding percentage. This is calculated by taking the team's offensive rebounds and dividing it by the team's offensive rebounds plus the opponent's defensive rebounds. This information can be compared against the rest of the league and a coach can determine if his team is averaging a lot of offensive rebounds per

game because they perform at a superior level in this area or because they have an unusual amount of opportunities due to poor shooting.

Percentage analysis can be used for any statistic both on the offensive or defensive side of the ball. The information provided by this analysis can be used to compare one's team against one's opponent similar to efficiency analyses. However, percentage analysis is also useful because it lets a coach know immediately following a game how his/her team did in any one aspect of the game. This immediate analysis can be examined by the coach to give him/her a sense of what to look for when reviewing the game tape. The percentage analysis can also be compared from game to game to give the coach a sense of the progression or digression of their team in a certain area over the course of the season. Such information can enable a coach to make adjustments to practice plans through the course of a season if they notice that their team has struggled in a particular area over an extended amount of games.

While box-score statistical analyses can provide coaches with valuable information on how his/her team is performing in certain aspects of the game, the information that can be gained from these analyses are limited in their depth. For example, box score statistical analyses can tell a coach his/her team's offensive efficiency rating, but it gives no insight into why a team's offensive rating is what it is or how a team's offensive rating can be improved. In order to gain answers to these questions it is necessary for a team to chart their games. Charting a game consists of manually tracking any aspect of the game in which one wants to gain a deeper understanding.

An example of how game charting can give a coach a deeper understanding of his/her team's offensive rating is seen in a study designed to measure the productivity of the Sacramento Kings' players on different types of offensive plays (Peterson, 2005). The study categorized every type of offensive play one would encounter during the course of a game and then measured the productivity of each player for each individual offensive play. Charting this information allows a coach to see how efficient each of his/her players and team are at every kind of offensive play. This sheds some light on why his/her team's offensive rating is what it is, and the coach can begin to design adjustments that will better meet the players' offensive strengths.

Adding the information gained from box-score analyses and game charting to the information gained by watching film provides a coach with abundantly more information about his/her team and their opponents than watching film alone. This added information gives a coach a competitive advantage over his/her counterpart who only utilizes video to prepare for a game, because the additional information can help him/her better prepare his/her team for the game and increase his/her likelihood of success.

However, one problem with basketball statistical research and game charting is that the field is relatively narrow. In nearly every aspect of basketball statistical research and game charting there are more studies done on the NBA than on college basketball. This might be because there are far fewer teams in the NBA with more extensive coverage making it easier to retrieve data and examine the entire population. This has left a limited amount of public research of this kind done on college basketball. Since the college and professional game is different it is difficult to transfer the findings of the

professional game to the college game. Therefore, it would benefit college basketball coaches if more statistical research and game charting research were focused on college basketball.

Since studies using box scores (Akers et al., 1991; Chatterjee et al., 1994; Onwuegbuzie, 2000) have supported the philosophy held by Oliver (2004) that there are four critical aspects to winning a game, namely field goal percentage, offensive rebounds, turnovers, and free throws, it would seem to be most beneficial to college coaches if more information was gained on how to improve in these areas.

Since the Oliver (2004) philosophy on how to win a game is based on outcomes, it would benefit coaches if research was done examining what occurred during the actual playing of the game that leads to greater efficiency in these outcomes. A study was done on the NBA that involved game charting the number of touches per possession and dribbles to end a possession's effect on points per possession (Game, 2008). This enabled data to be collected on how touches per possession and dribbles to end a possession affected the most important element of offensive efficiency, points per possession. It also enabled additional information to be gathered on factors that affect points per possession such as field goal percentage, turnovers, and fouls.

The study (Game, 2008) gives coaches a better idea of what is transpiring during the course of a game that leads to an efficient achievement of the outcome based suggestions made by Oliver (2004). With this type of information inferences can be made on what type of offensive activity (multiple passes, multiple dribbles, or a combination of both) leads to the most efficient results in the area's deemed critical to

winning (Oliver, 2004). With multiple offensive systems available, some emphasizing the pass and some emphasizing the dribble, this could serve as valuable information for coaches trying to determine which type of offensive system to choose for their team. It could also serve as a tool for coaches to determine if their current offensive system is the best choice for their team.

Since there is no study of this nature done on college basketball, it would be beneficial for coaches if one was completed and made public. In doing so one could follow the model created by the study done on the NBA (Game, 2008). However, it would also be helpful to coaches if post touches were charted in addition to touches and dribbles-to-end-a-play (DEP) because this will allow the coaches to see the impact post players have on scoring efficiency.

It would also be beneficial to coaches if the elements examined in the NBA study (Game, 2008) were evaluated based on plays as opposed to possessions. This is because possessions do not end with an offensive rebound (Kubatko et al., 2007), which has the potential to skew data towards high amounts of touches when an offensive rebound is passed out to the perimeter in an attempt to start a new offensive sequence. This problem can be solved by tracking plays instead of possessions because when an offensive rebound is passed out to the perimeter to start a new offensive sequence this will also start a new play. This allows the results to more realistically represent what strategies (touches or dribbles) teams are implementing in an attempt to score.

After talking with a Division I men's basketball coaching staff it was felt that adding elements neglected by the study on the NBA (Game, 2008) would provide

empirical evidence on anecdotal theories held by coaches concerning ball movement, dribbles, and post touches. Therefore, the primary purpose of this study will be to use game charting techniques to evaluate the effects touches per play, post touches per play, and DEP have on points per play. Secondary purposes will be to evaluate the effects touches per play, post touches per play, and DEP have on field goal percentage, turnovers, and fouls.

Methods

Participants

Participants in this study were one Division I men's basketball team and their Division I opponents for the 2006-07 and 2007-08 seasons, which included 32 different teams over 68 games.

Pilot Study

Pilot data were collected on three Division I men's college basketball games. The purpose of the pilot study was to refine methodology and determine the number of games on which to collect data. From the pilot study it was determined that data would be manually collected on a score sheet for play number, touches, post touches, DEP, assists, offensive rebounds, the play's outcome, and the number of points the play produced. It was also found from the pilot data that a typical Division I men's basketball game consists of 60-80 plays per team for a total of 120-160 plays per game. From this information it was determined that charting 68 games or two seasons worth would result in data on approximately 10,000 plays providing sufficient data for this study.

Data Sources

Data were collected using game film from one Division I men's basketball team for the 2006-07 and 2007-08 seasons. Previous to this study, video of every game this team played during the two seasons was digitally captured into video editing software called DV Sport (DV Sport Inc., Pittsburgh, PA). Then using DV Sport, the team's video coordinators edited each game, separating their offensive possessions from their opponent's offensive possessions, making it more efficient to view each team's offensive possessions because of the elimination of dead time that occurs in a typical basketball game. During this process the offensive possessions for each team were automatically coded in numerical order that coincided with the order that the possession occurred in the game, therefore each team's first offensive possession would be coded number one. All 68 games were viewed using DV Sport and charted manually using a score sheet created specifically for this study using information gathered during the pilot study.

Procedures

This study utilized game film from one Division I men's basketball team over the 2006-07 and 2007-08 seasons. Each game played during those two seasons was viewed and manually charted by a researcher using a score sheet designed for this study. After manually recording the data from the game on a score sheet the information was transferred to a Microsoft Excel spreadsheet that was identical to the score sheet, except for the addition of the categories: scout team, opponent, home team, and date. These columns were added to the electronic version to make it possible to differentiate between

home team and visiting team, and determine which team's offensive plays were being examined.

For the purposes of the study, it needed to be determined if data would be charted according to possessions or plays. Although possessions are desirable because they are relatively equal for both teams, it was felt that plays would be more appropriate for this study. This is because possessions can result in multiple plays as a result of offensive rebounds. It was felt this could skew the data unrealistically towards large counts of touches and post touches since offensive rebounds are sometimes passed back out to the perimeter in order to start a new offensive play. Therefore it was felt that using plays would better represent what strategies teams were trying to implement in order to score.

Offensive plays will only be counted if they originate from a realistic scoring position, which for this study will be within 25 feet of the basket. This eliminates fluke plays such as a player making a shot from behind half-court.

Every play will begin with the first touch that occurs within scoring position. The following activities will constitute the end of a play: made field goal, common foul, turnover, defensive rebound, or deflection out of bounds. If the play results in a shooting foul then the play will conclude with the making of the final free throw or the rebound of a missed free throw and the points from the free throws will be attributed to the possession in which the shooting foul occurred. In the case of offensive rebounds, if the player who secures the offensive rebound immediately goes back up for a shot then it will be counted as a continuation of the original play, thus eliminating multiple one possession plays that would unrealistically skew data for single touch plays. However, if

the offensive rebounder passes the ball out to another player in an attempt to restart the offense, then a new play will be counted starting with the touch of the player restarting the offense.

It was also determined that only half-court offensive plays would be examined. This was done to eliminate transition baskets which usually require few passes and primarily result in lay-ups or uncontested shots. During this study, a transition play will be any occurrence where the offense has more players in scoring position than the defense has defenders.

Touches will only be counted when they occur within a realistic offensive scoring position. The first touch can be as a result of a player dribbling the ball into scoring position or as a result of a player passing the ball into scoring position. This eliminates touches that might occur before a team reaches scoring position such as outlet passes, passes to defeat a defensive press, or any other situation that might warrant additional touches before reaching scoring position. Also, each time a player touches the ball within scoring position it is counted as a touch. For example, if a play sequence was Johnson, Clark, Brown, Clark, it would count as four touches. In the instance when a team is taking the ball out of bounds within scoring position then the player passing the ball in bounds is counted as the first touch. For example, if Jones was taking the ball out of bounds under his team's basket and passed it to Matthews who immediately took a shot, it would count as two touches. This method was used because it is possible to record an assist from an in-bound passer.

Post touches will be included in the touch total for each play, but they will also be charted separately in order to examine what effect post touches have on offensive basketball. Post touches will be counted each time a player touches the ball with his back towards the basket within the offensive post area. The offensive post area will be considered anywhere within 8 feet of the basket. Stipulating that a player must originally have his back towards the basket eliminates post touches that might occur as a result of a player driving to the basket and passing to a teammate in the post area for a lay-up. In the researcher's mind that situation should be considered a touch since the result of the play is primarily determined by the driving player. It is the adjustment of the defense to the post player's touch which is of primary interest in this study. It should also be noted that it is not necessary for a player to be a post player to record a post touch.

The total number of dribbles by the player who terminates the play will be counted. Again, only dribbles that occur within scoring position will be counted. This eliminates all dribbles that take place behind half-court in order to advance the ball into scoring position. It also eliminates a play where a player dribbles the ball off his foot out of bounds behind half-court or any other similar play.

Assists and offensive rebounds were determined by the researcher following the guidelines established for each statistical category by the NCAA for college basketball.

In the outcome column is a description of how the play concluded. The following outcomes are possible: 2 make, 2 miss, 3 make, 3 miss, 2 make + foul, 3 make + foul, foul, turnover, and deflection out of bounds. The point's column will list how many points were scored on that play.

Ensuring Data Accuracy

While parameters were established to ensure that the data collected is reliable and accurate, there are some levels of subjectivity required by the researcher, namely determining when a player is within scoring position, determining when a player is in the post area, and determining when an assist should be credited. To ensure that the data were recorded accurately there was a categorical audit performed on the three areas in question.

The auditor was first trained on how the games were charted for this study and shown plays dealing with the three subjective areas. This was done by showing the auditor 10 plays each of what is acceptable scoring position, acceptable post position, and what constitutes an assist. The auditor was then shown 10 plays each of what is not acceptable scoring position or post position, and what would not be constituted as an assist. Lastly, the auditor was shown 10 plays for each of the three categories that represent a gray area where the auditor would have to use their judgment to determine what to record.

Following the training session the auditor went through a practice session where he was shown 100 different plays and told to chart the plays following the guidelines learned during the training session. The practice session was designed to allow the auditor to ask any additional questions about charting the plays, become comfortable with the process, and gain experience judging between the subjective elements of the study. The practice session was not concluded until the auditor's questions were answered and he verbalized that he felt comfortable and confident charting plays.

After the practice session was completed the auditor and the researcher were shown the same 100 plays and asked to chart them using the manual score sheet designed for this study. At the conclusion of the 100 plays the game sheets of the auditor and the researcher were compared for each of the three subjective areas in this study. The charts of the auditor and researcher had an agreement rate of .97 for touches, .95 for post touches, and .95 for assists, for a total agreement rate of all three areas of .957. Based on the high agreement rates of all three areas examined during the categorical audit it was determined that the data were collected in a reliable and accurate manner.

Data Analysis

The data collected were statistically analyzed using Bayesian hierarchical models and implemented using WinBUGS software (MRC Biostatistics Unit, Cambridge, UK). Bayesian models were selected because they allow for estimation of a large number of parameters and because they determine the posterior distribution of parameters by combining previous knowledge concerning parameters with the current data. This makes it possible to include parameters associated with basketball that are not easily estimated, e.g. unequal opponent strength and home court advantage.

For the points per play dependent variable, a Poisson likelihood was assumed. The likelihood chosen was

$$y_i \sim Poisson(\lambda_i),$$

where λ_i is the expected number of points scored per play. Now we let

$$log(\lambda_i) = \kappa_h + \delta_o + X_{t,j}\alpha_{t,j},$$

where

t=1,…,32, the number of teams,
j=1,…,10, the number of independent variables considered,
h=1,…,16, the number of home teams, and
o=1,…,31, the number of opponents.

It is this formulation that allows the effect of the various independent variables to be assessed. This is done by modeling the log of λ_i as a function of home team effect (κ_h), opponent effect (δ_o), and a linear combination of the effects of number of touches, number of post touches, and number of DEP have on points per play.

Now focus on $X_{t,j}\alpha_{t,j}$ with the $X_{.j}$ of interest being

an indicator variable for an assist,
an indicator variable for an offensive rebound,
the number of touches if touches are from 0 to 9,
an indicator variable if the number of touches are 10 or more,
the number of dribbles if the number of dribbles is from 1 to 3,
an indicator variable if the number of dribbles are 0,
an indicator variable if the number of dribbles are 4 or more,
an indicator variable if the number of post touches is 0,
an indicator variable if the number of post touches is 1, and
an indicator variable if the number of post touches is 2 or more.

Thus, the parameters associated with assists, total touches, DEP, post touches, and offensive rebounds are estimated using this formulation. This structure has been set up to allow the effects of total touches, post touches, and DEP to have a different effect depending upon the level at which they occur. These levels were chosen by a Division I men's basketball coaching staff and reflect their beliefs about the likely effect of performing these skills at the levels indicated. These levels essentially mean that threshold functions were created for these variables as described above (Figure 1). This figure shows a hypothetical example where there is a negative effect for zero dribbles, a

positive linear effect if dribbles number from 1 to 3, and a negative effect for more than 3 dribbles.

For a Bayesian analysis, prior distributions must be specified for all parameters. To enrich the structure of the model, we also assumed that all the parameters were drawn from populations of possible parameters for the specific covariate. It is this assumption that leads to the hierarchical nature of the model. Formally we assumed

$$\kappa_h \sim N(\mu_\kappa,\sigma_\kappa^2) \qquad \delta_o \sim N(\mu_\delta,\sigma_\delta^2) \qquad \alpha_{t,j} \sim N(\mu_{\alpha_j},\sigma_{\alpha_j}^2).$$

Thus, there are different parameters for each home team, each opponent, and for each covariate associated with each team in the data set for λ_i.

The hyperpriors, or the priors for each of the population parameters, were assumed to be

$$\begin{array}{ll} \mu_\kappa \sim N(0,1000) & \sigma_\kappa^2 \sim IG(2.01, .001) \\ \mu_\delta \sim N(0,1000) & \sigma_\delta^2 \sim IG(2.01, .001) \\ \mu_{\alpha_j} \sim N(0,1000) & \sigma_{\alpha_j}^2 \sim IG(2.01, .001)\ \forall j. \end{array}$$

For the probability variables examined in this study, shooting percentage (probability a shot is made when attempted), offensive rebound (probability an offensive rebound is secured on a missed shot), and foul (probability a foul is committed by the defense) a Bernoulli likelihood was assumed:

$$y_i \sim Bernoulli(\theta_i),$$

where θ_i is the probability of an event (e.g., field goal). Within the likelihood we let

$$logit(\theta_i) = \zeta_h + \gamma_o + X_{t,j}\beta_{t,j},$$

where

t=1,…,32, the number of teams,
j=1,…,10, the number of variables considered,

h=1,…,16, the number of home teams, and
o=1,…,31, the number of opponents.

The same covariate structure used for points per play was used for the probability variables. That is, we used the same levels and threshold functions as were used in the points per play model.

For the prior distributions, similar assumptions were made as for points per play. It was assumed

$$\zeta_h \sim N(\mu_\zeta,\sigma_\zeta^2) \qquad \gamma_o \sim N(\mu_\gamma,\sigma_\gamma^2) \qquad \beta_{t,j} \sim N(\mu_{\beta_j},\sigma_{\beta_j}^2),$$

so that a similar hierarchical structure exists. The hyperpriors were also similar. It was assumed

$$\mu_\zeta \sim N(0,1000) \qquad \sigma_\zeta^2 \sim IG(2.01, .001)$$
$$\mu_\gamma \sim N(0,1000) \qquad \sigma_\gamma^2 \sim IG(2.01, .001)$$
$$\mu_{\beta_j} \sim N(0,1000) \qquad \sigma_{\beta_j}^2 \sim IG(2.01, .001)\ \forall j.$$

The depth and richness of analysis a Bayesian hierarchical model can achieve is what makes it so valuable when analyzing sports data. For example, in this study we are estimating 367 parameters (32 teams * 10 regression parameters per team + 31 opponents + 16 home teams) in each model.

The effects of primary interest (touches per play, post touches per play, and DEP) were determined to significantly affect the outcome variables under consideration (points per play, field goal percentage, offensive rebound, and fouls) if the posterior probability that the parameter value was not zero was equal to or greater than .95. However, if the posterior probability that the parameter value was not zero was less than .95 then it was

determined that the effects of primary interest did not significantly impact the outcome variables under consideration.

Results

With 32 different teams being a part of this study, plots can become muddled and difficult to read. Therefore, to make it easier to read the plots and to distinguish between different teams, nine teams were color coded and put on the plots. The main team observed for this study is coded dark blue, while the other eight teams color coded on the plots represents the additional teams that make up the dark blue team's conference. These teams are color coded red, orange, black, grey, yellow, green, purple, and light blue. There are four different plot sheets each representing an outcome variable under consideration (points, field goal percentage, turnovers, and fouls). On each of the four plot sheets there are ten different plots with each plot showing the effect one of the ten independent variables considered in this study (assists, offensive rebounds, touches one through nine, touches ten plus, dribbles one through three, zero dribbles, dribbles four plus, zero post touches, one post touch, and two plus post touches) had on the outcome variables (Figures 2-5). On each plot the vertical red line represents zero, the black dashed curve represents the overall curve when considering every team's performance in the study, and the blue decimal number below the title of the individual plots represents the posterior probability that the parameter value for the dark blue team is not zero. The dark blue team was the main team analyzed in this study and their data makes up half of all the data analyzed for this study.

Points Per Play

For the outcome points per play (Figure 2), the assist variable has a perfect positive relationship. This was expected since points must be scored in order for an assist to be recorded. On plays where an offensive rebound is secured a majority of the teams have a statistically significant increase in points scored per play. However, the light blue team does not follow the trend of the other teams and offensive rebounds do not tend to lead to points for them.

As touches increase up to nine there seems to be differing results for different teams. For some of the teams (grey, green, yellow) as touches increase the likelihood of points being scored decreases. Other teams (dark blue, light blue, black, purple) seem to have a slight increase in the likelihood of points being scored as their touches increase up to nine, however this increase is not statistically significant. For two teams (orange, red) as touches increase up to nine the likelihood of them scoring points increases at a statistically significant level, suggesting that these two teams greatly benefit from sharing the ball with teammates. However, as touches increase to ten or more there seems to be a slight negative effect on points scored for most teams. This is especially true for the black team whose points per play production is more negatively affected by touches exceeding nine than any other team in the conference.

With teams shooting off zero dribbles, only the dark blue team saw the likelihood of their point production increase at a statistically significant rate. All the other teams' point production decreased when they took shots without first dribbling. As dribbles leading into a shot increased up to three, all teams except red, saw an increase in point

production. However, once the number of dribbles leading into a shot exceeded three, every team in the conference saw a negative effect upon the likelihood of points being scored.

The effect of zero and one post touch does not seem to be very significant when considering point production. A majority of the teams hover around zero for zero and one post touch, with the exception of purple and black who with one post touch seem to have an increase in point production. When teams have two or more post touches they seem to have varying success. The dark blue, light blue, grey and yellow teams' point production is all negatively affected when they have multiple post touches per play, while multiple post touches seem to have a slight positive impact upon point production for the purple, green and black teams. Also worth noting is that the dark blue team's (which constitutes half the data generated for this study) spreads for both one post touch and multiple post touches per play are very wide, suggesting that they had very inconsistent post play during the course of this study.

Field Goal Percentage

Similar to the points per play outcome, the assist variable for the field goal percentage outcome (Figure 3) can be ignored since field goal percentage is going to be 100% on any play where an assist is recorded. However, securing an offensive rebound on a play seems to significantly increase field goal percentage for a majority of the teams in the conference.

As touches increase from one up to nine, seven of the teams in the conference improve their field goal percentage. However, the green and light blue teams' field goal

percentages decrease as they increase the number of touches up to nine. When touches exceed nine only purple and light blue seem to slightly improve their field goal percentage, while the other seven teams appear to be at zero or have a negative effect upon their field goal percentage.

Every team in the conference sees their field goal percentage decrease when they shoot off zero dribbles. As dribbles leading into a shot increase from one up to three, every team in the conference with the exception of red sees an increase in their field goal percentage. However, as the number of dribbles leading into a shot exceeds three, every team in the conference sees a negative effect upon their field goal percentage.

Similar to the points outcome, zero post touches seems to have very little effect upon field goal percentage with a majority of the teams hovering around zero. Having one post touch seems to slightly increase field goal percentage for many of the teams, with the purple, black, and red teams seeing the most benefit. Although, any benefit gained with one post touch is lost when teams have multiple post touches within a play. Every team has a negative effect upon their field goal percentage when they have multiple post touches, with the purple team seeing the most drastic difference in field goal percentage from one post touch to multiple post touches.

Turnovers

Since turnovers have a negative effect upon a team's offense, it is good to be left of zero on the turnover plots since this means the team is reducing the likelihood of having a turnover (Figure 4). Again, the assist plot can be ignored since it is impossible to have an assist and a turnover on the same play. Also, securing an offensive rebound

on a play statistically significantly reduces the likelihood of having a turnover for every team in the conference.

As touches increase from one up to nine every team except for purple reduces their likelihood of having a turnover. When touches exceed nine teams are closer to zero, but still reduce the likelihood of having a turnover with the exception of the light blue team.

When there are zero dribbles on a play the conference seems to be split with half the teams increasing their likelihood of a turnover and the other half decreasing the likelihood of a turnover. As dribbles increase from one up to three a majority of the conference decreases the likelihood of a turnover. However, the dark blue team is significantly worse than the rest of the conference when dribbles increase from one up to three. When dribbles exceed three, a majority of the teams center around zero with some of the teams slightly increasing the likelihood of a turnover and others slightly decreasing the likelihood of a turnover.

Zero post touches leads a majority of the teams to reduce the likelihood of a turnover, but only slightly. With one post touch a majority of the teams' center around zero, however, the grey team seems to increase their likelihood of turnover, while the black team decreases the likelihood of a turnover. When teams have multiple post touches within a possession there are more varying results with turnovers. It greatly reduces the dark blue team's likelihood of a turnover, while the grey team's likelihood of a turnover greatly increases.

Fouls

When a team has an assist on a play the likelihood of there being a foul is significantly reduced for every team in the conference (Figure 5). This is expected since there are comparatively very few "and one" fouls that occur. When teams secure offensive rebounds there is a statistically significant reduction in the likelihood of a foul being called for every team in the conference.

As touches increase from one up to nine all of the teams in the conference reduce the likelihood of a foul with the exception of the red team and when touches exceed nine every team in the conference decreases the likelihood of a foul.

When there are zero dribbles on a play every team in the conference reduces their likelihood of being fouled. As dribbles increase from one up to three, only the yellow team slightly increases their likelihood of obtaining a foul. However, when dribbles exceed three, the dark blue team and light blue team both increase their likelihood of getting fouled.

Zero post touches seems to reduce the likelihood of being fouled for every team in the conference with the exception of the red team who appears to be centered on zero. One post touch seems to have a minimal effect upon fouls with a majority of teams being centered around zero. However, when teams have multiple post touches it seems to reduce the likelihood of teams being fouled with the exception of the green and orange teams that seem to both center on zero.

Discussion

This study analyzed the effect that the offensive variables touches, dribbles, post touches, assists, and offensive rebounds had on the outcome variables points, field goal percentage, turnovers, and fouls. This was done to serve as a starting point for additional game charting studies to be done on college basketball. It was also designed to provide empirical evidence on anecdotal theories held by coaches concerning ball movement, dribbles, post touches, and offensive rebounds.

When dealing with ball movement many coaches will teach their team to keep the ball moving because the more times the ball is passed from player to player the more the defense has to move, causing gaps to occur in the defense leading to open shots. This belief is taught by coaches when they tell their team to "make an extra pass in order to turn a good shot into a great shot." This study seems to support the idea held by coaches that multiple passes will lead to better shots, at least up to a point. From this study it was determined that as teams increased their touches from one up to nine a majority of teams increased their likelihood of scoring points, increased their likelihood of shooting a higher percentage, and decreased their likelihood of turning the ball over. All of these variables lead to better offense and seem to support the idea that more passes lead to better offense. However, there seems to be a cap on how many passes is beneficial to a team. When teams had 10 or more touches on a single play a majority of them saw a decrease in the likelihood of scoring points and a decrease in shooting percentage. This suggests that once a team surpasses 10 touches there is a negative effect upon their shooting and point production. This can in part be explained by the notion that once a

team has had 10 or more touches they are likely near the end of the 35 second shot clock and might be forced to take a shot they are unaccustomed to shooting.

While some coaches implement the pass into their offense in order to generate good shot opportunities, other coaches use the dribble to accomplish the same thing. For this study DEP was examined in order to determine whether teams perform better offensively with the dribble or without the dribble. According to this study, every team in the conference saw their field goal percentage decrease when they took a shot without dribbling and only one team (dark blue) significantly increased their likelihood of scoring points when they took a shot without dribbling. In addition, when teams increased the number of dribbles leading into their shot from one up to three every team except one (red) saw an increase in the likelihood that they would score points and an increase in their field goal percentage. A majority of the teams also decreased the likelihood of having a turnover. However, once a team exceeded a certain number of dribbles (four or more) they saw a negative effect upon their offense. For all the teams, once they took four or more dribbles the likelihood of them scoring decreased, their shooting percentage decreased, and for most teams the likelihood of a turnover increased. This suggests that while increasing your dribbles from one to three is beneficial for a team's offense, using more than three dribbles is detrimental. A decrease in offensive production when exceeding three dribbles might be due to the fact that a player is dribbling out a shot clock and taking a shot at the end of the clock or that a player is trying to force an offensive opportunity with the dribble when one does not exist. Regardless, it would

seem beneficial to teams to implement the dribble into their offense because taking up to three dribbles leading into a shot tends to increase the productivity of an offense.

The result that shooting off the dribble increased shooting percentage and shooting with no dribble decreased shooting percentage was contradictory to what was expected when the study was conducted. It was expected that catch and shoot situations off of passes from the post and passes around the perimeter would lead to an increase in shooting percentage, while players trying to create their own shot off the dribble would lead to a decrease in shooting percentage. That shooting increases off the dribble as compared to off zero dribbles might be due to the fact that dribbling puts the shooter closer to the basket at the time of the shot and can lead to lay-ups. Such results suggests the importance of implementing the dribble into one's offense.

The most surprising results of the study were the lack of impact post play had on offense. It has long been believed by coaches that passing the ball into the post area leads to better offense. However, on all four outcome variables for both zero post touches and one post touch a majority of the teams were centered close to zero, suggesting that zero post touches and one post touch had little impact upon the variables examined. When multiple post touches were examined there was more of an effect, however, only three of the teams increased their likelihood of scoring, zero teams increased their field goal percentage, and five teams increased their likelihood of a turnover. Therefore, a majority of the teams decreased their offensive productivity when having multiple post touches. The fact that post play did not have more of an effect than it did is surprising, but one explanation for it might be because of the inconsistent play received from the post by the

teams examined. The dark blue team, whose data made up half of the data collected for this study, has a very wide spread for all of its post curves which suggests that post play was very inconsistent for them over the course of the study.

Another explanation could be the evolution of basketball, where three point shooting, more athletic power forwards, and centers that can shoot from the outside has become more common than traditional back to the basket centers. However, more data would have to be collected on more teams in order to make this claim, yet data from this study suggests that post play might not be as significant to offensive basketball as previously believed.

While different offensive variables seem to have different effects on the outcome variables depending on the team examined, the most universal positive offensive variable was offensive rebounding. For a majority of the teams, an offensive rebound statistically significantly increased the likelihood of them scoring points. For all the teams an offensive rebound increased their field goal percentage and decreased the likelihood of having a turnover. The positive effects associated with offensive rebounds for every team in the study would suggest that securing offensive rebounds is very beneficial for offensive basketball. These results might lead coaches who traditionally send two of their players back to prevent transition points to consider the added benefit of sending an additional player to the basket in hopes of securing an offensive rebound.

Another variable to consider when interpreting the data is style of play and personnel. The light blue team uses the Princeton offense as its primary offense. One possible reason they use this offense is because of their lack of height. The Princeton

offense is designed to offset a lack of height by spreading the floor and using back-cuts to create lay-ups and open three-point shots. Knowing the light blue team's style of play and personnel helps explain why they were the only team in the study to not increase their points per play when securing an offensive rebound. It also helps explain why points per play and shooting percentage decreased when they had at least one post touch during the play because their offensive scheme and personnel is not designed to score out of the post in the traditional sense.

It is also interesting that the two teams (dark blue and red) considered having the most dominating post players in the study did not see the most significant results when the ball was passed into the post. While the red team increased their field goal percentage with one post touch, both dark blue and red did not see a significant increase in points per play when passing it into the post. Conversely, two teams (black and purple) not known for their post play saw significant increases in points per play and field goal percentage when they had a post touch. This suggests that even though they did not utilize the post as often as some of the other teams, when they did they were rewarded. These results allude that both the black and purple team would have benefited had they passed the ball into the post more often. A possible reason they did not is because they might not have realized how efficient their post play had been, suggesting that teams can benefit from information gained through game charting.

This study showed that each offensive variable impacted the outcome variables for each team differently. This shows that each team has different strengths and weaknesses, which makes it difficult to categorize how a specific variable will affect a

specific outcome. However, from this study some trends were discovered. First, once a team exceeds nine passes and three dribbles they tend to have a decrease in points and field goal percentage, suggesting that there is a cap to how much passing and dribbling is recommended to produce an effective offense. Second, up to three dribbles into a shot was more productive and efficient than shooting with no dribbles. Third, post play does not have as big an effect on offensive basketball as previously expected. Lastly, offensive rebounds seem to universally have a positive effect upon offensive basketball.

This study seemed to support some anecdotal beliefs about basketball, while contradicting others. However, it is necessary for additional studies to be done on more teams in order to build a sample large enough to make wide sweeping conclusions about the trends discovered in this study. Hopefully this study will serve as a starting point for additional game charting studies to be done in order to better understand college basketball and help give coaches ideas as to how they can better prepare their teams for seasons to come.

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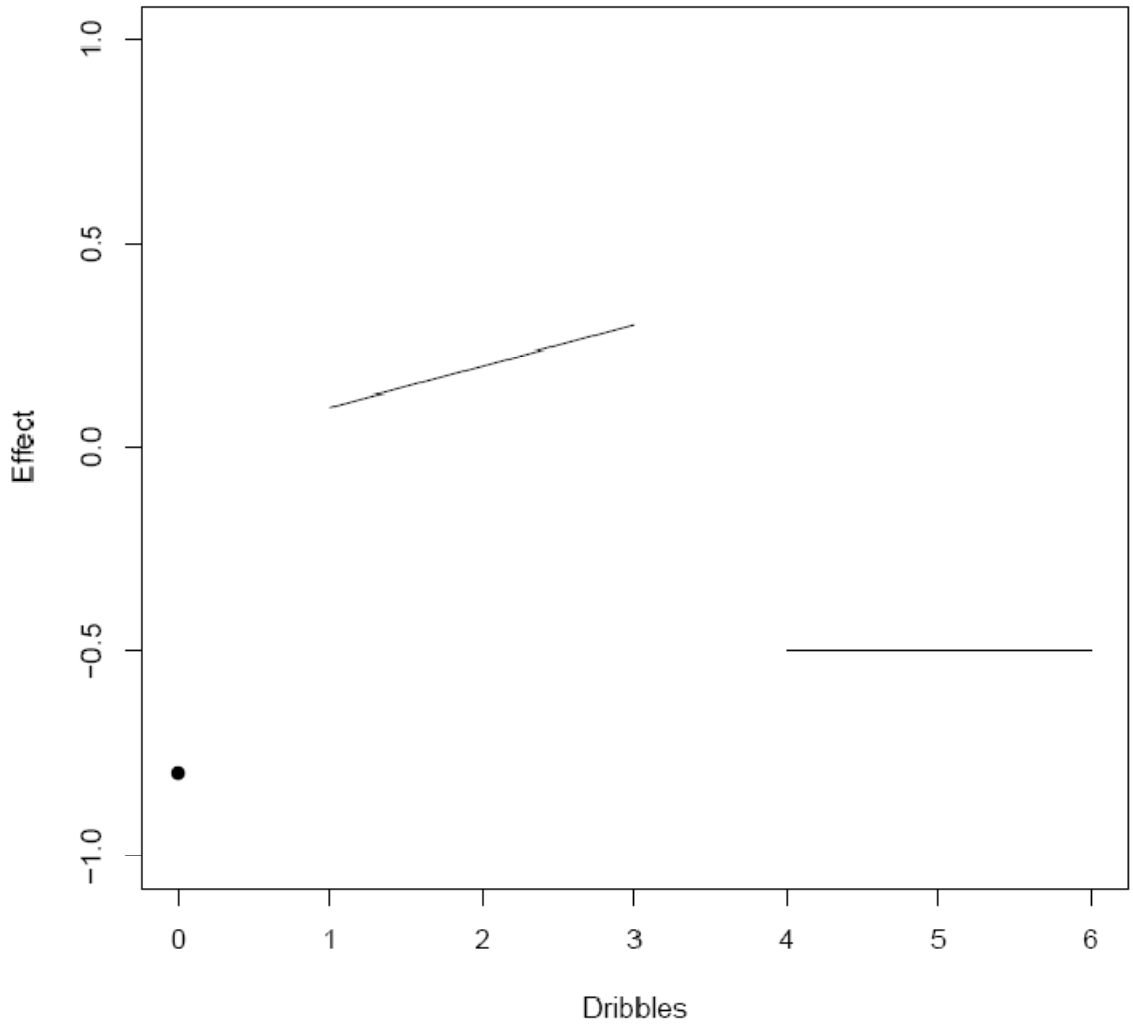

Figure 1. An example of a threshold function. In this example the effect of zero dribbles is negative, there is a positive linear effect if dribbles number one to three, and there is a negative effect if there are four or more dribbles.

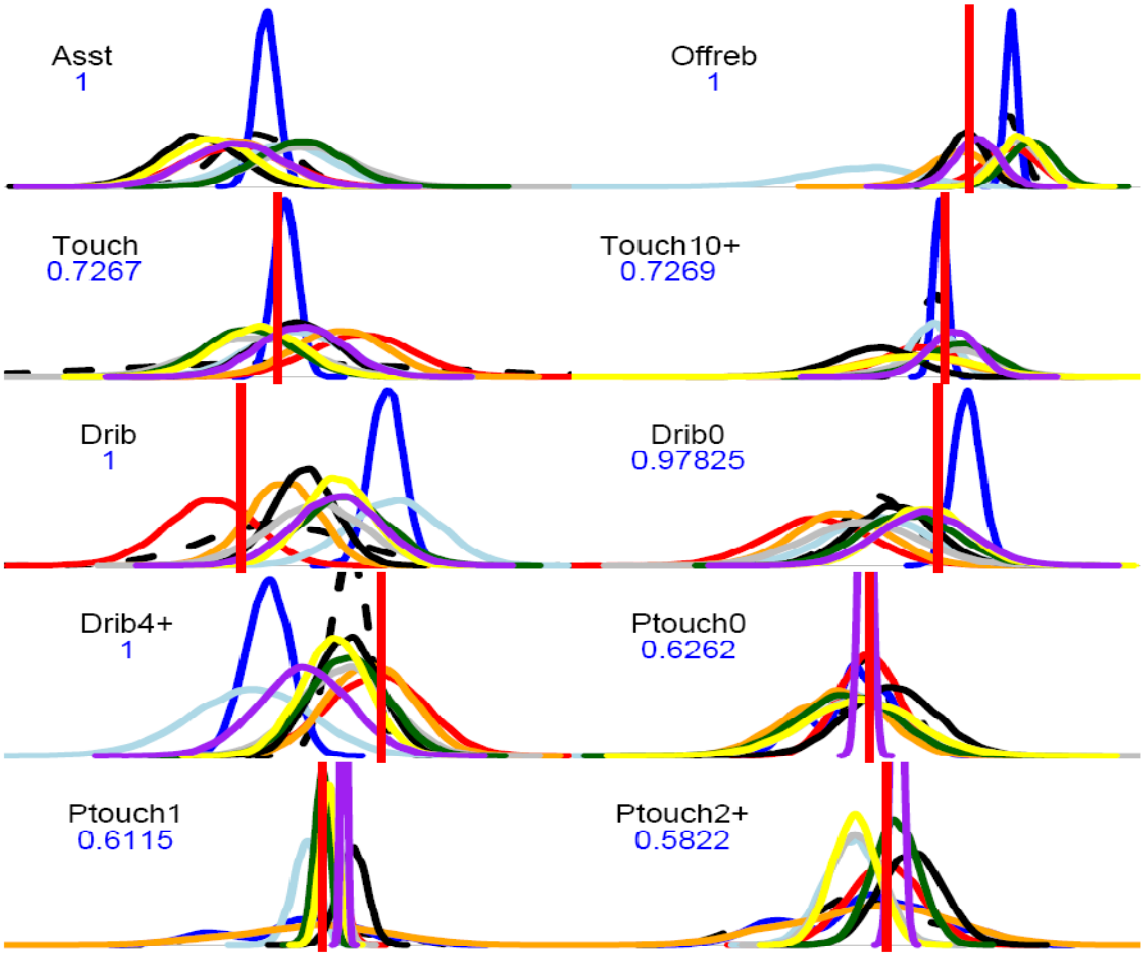

Figure 2. The points per play plot sheet. Posterior distributions of the parameters associated with the respective independent variables for the points per play dependent variable. The red line on each plot is at zero. The dark blue line is the posterior for the main team in the study. The number on each plot is the posterior probability that the parameter for the main team is not zero. The black dashed line is the posterior probability for μ_{β_j}, the parameter for the mean of all teams' performance. The other colored lines represent the posteriors for eight of the other teams in the study. These teams were chosen to represent various styles of play.

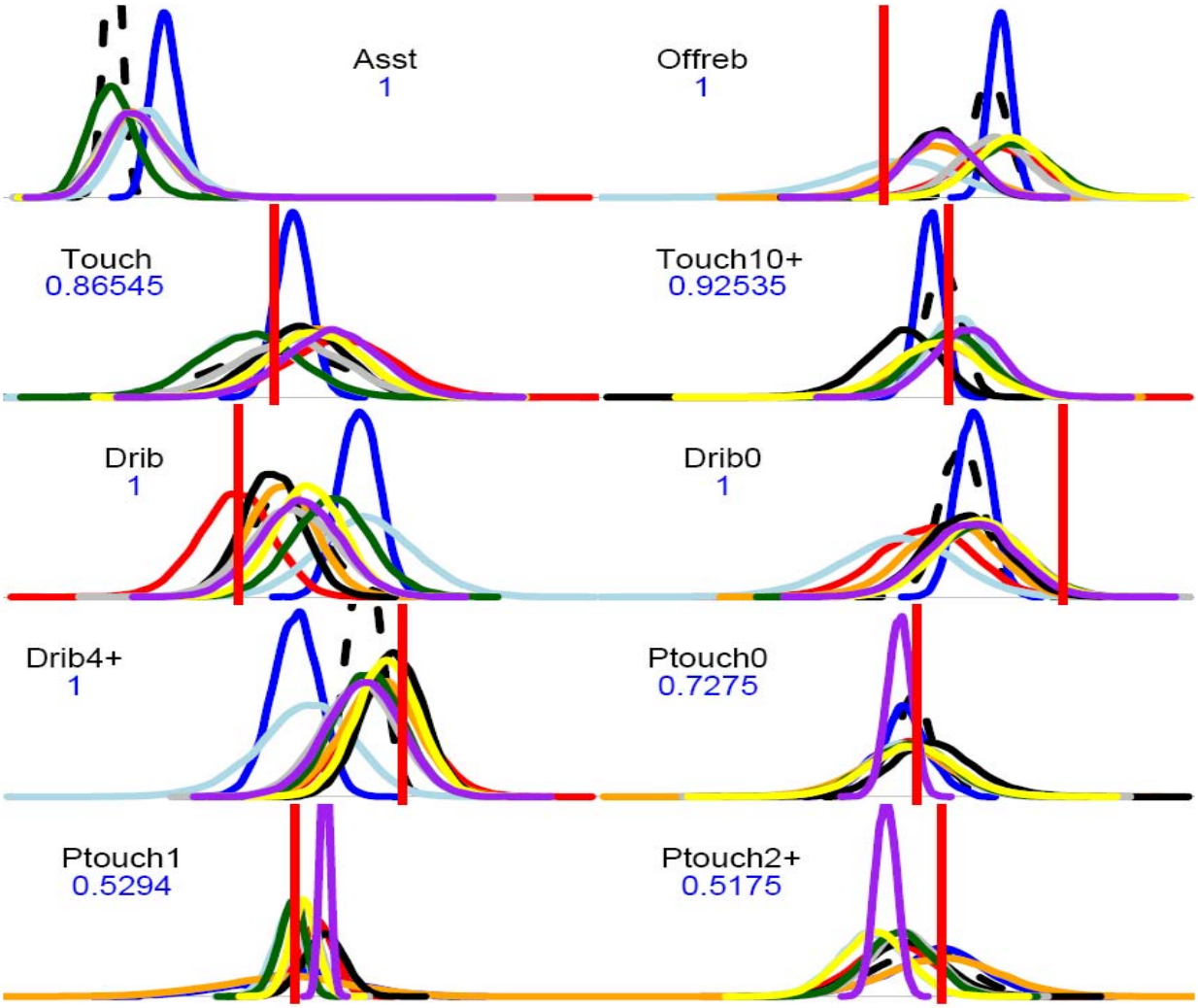

Figure 3. The field goal percentage plot sheet. Posterior distributions of the parameters associated with the respective independent variables for the field goal percentage dependent variable. The red line on each plot is at zero. The dark blue line is the posterior for the main team in the study. The number on each plot is the posterior probability that the parameter for the main team is not zero. The black dashed line is the posterior probability for μ_{β_j}, the parameter for the mean of all teams' performance. The other colored lines represent the posteriors for eight of the other teams in the study. These teams were chosen to represent various styles of play.

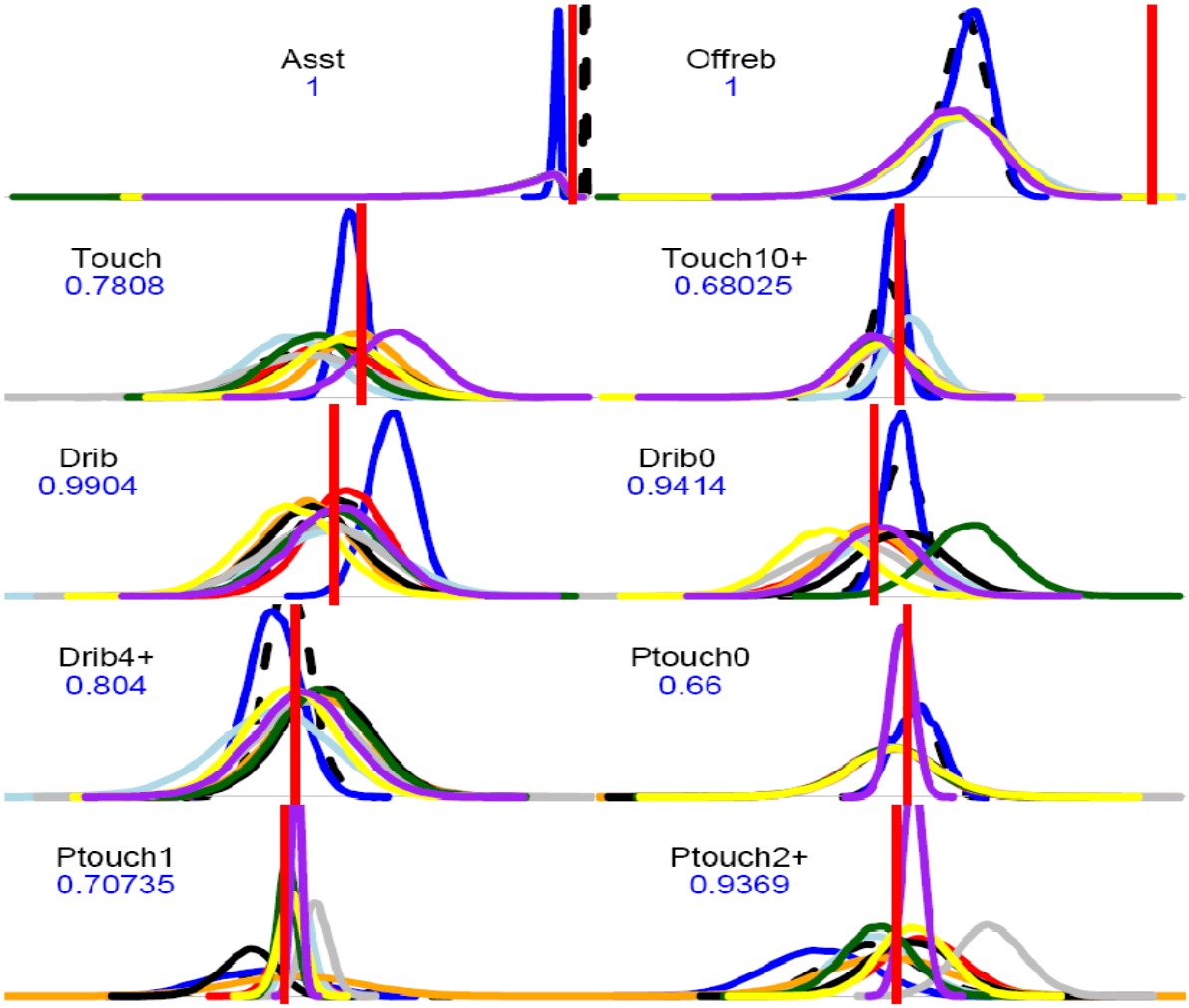

Figure 4. The turnover plot sheet. Posterior distributions of the parameters associated with the respective independent variables for the turnover dependent variable. The red line on each plot is at zero. The dark blue line is the posterior for the main team in the study. The number on each plot is the posterior probability that the parameter for the main team is not zero. The black dashed line is the posterior probability for μ_{β_j}, the parameter for the mean of all teams' performance. The other colored lines represent the posteriors for eight of the other teams in the study. These teams were chosen to represent various styles of play.

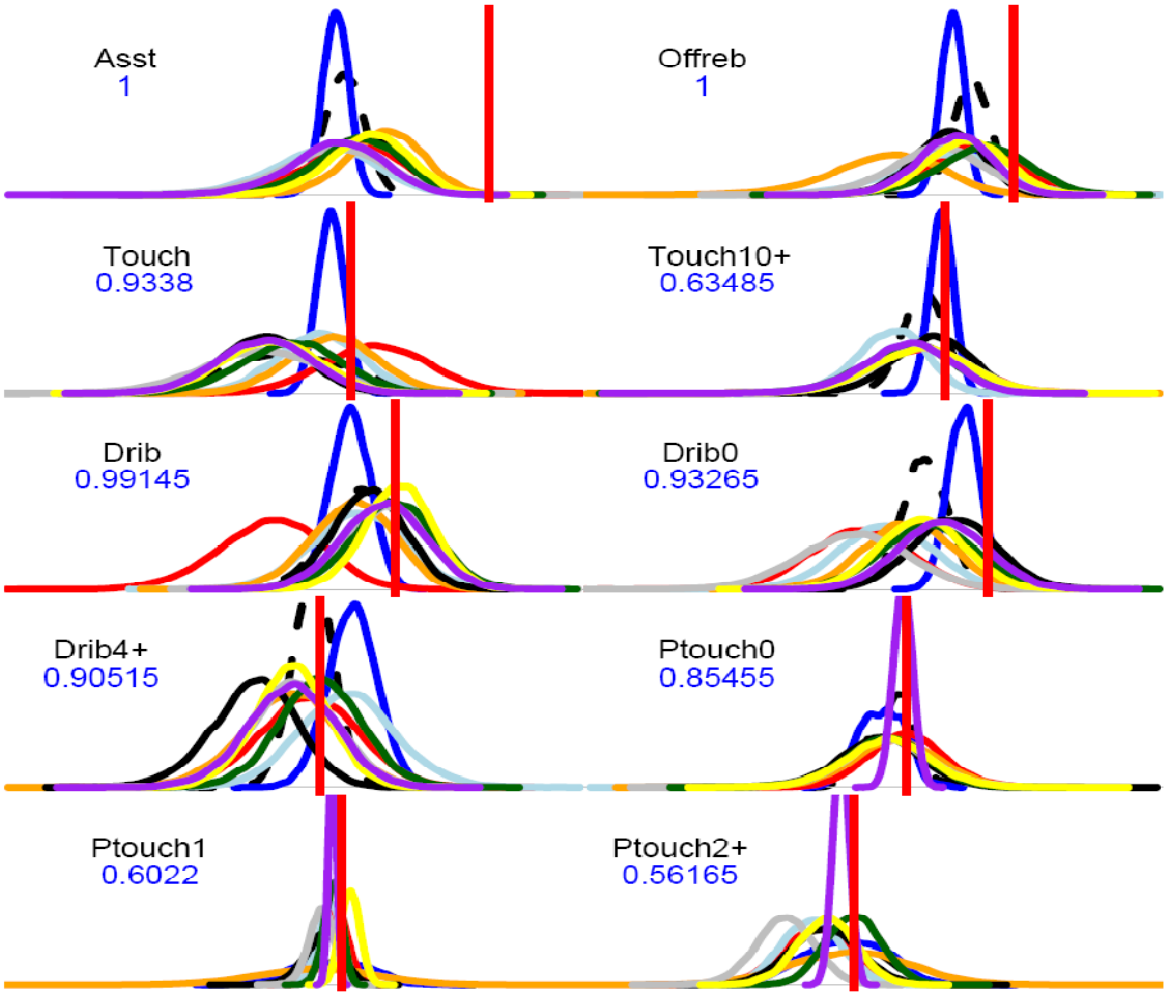

Figure 5. The fouls plot sheet. Posterior distributions of the parameters associated with the respective independent variables for the fouls dependent variable. The red line on each plot is at zero. The dark blue line is the posterior for the main team in the study. The number on each plot is the posterior probability that the parameter for the main team is not zero. The black dashed line is the posterior probability for μ_{β_j}, the parameter for the mean of all teams' performance. The other colored lines represent the posteriors for eight of the other teams in the study. These teams were chosen to represent various styles of play.

Appendix A

Prospectus

Chapter 1

Introduction

Basketball, which was created by James Naismith to better hold physical education students' attention during the winter months (Fox, 1974), has become a multi-billion dollar business at both the college and professional levels. In 1999 the Columbia Broadcasting Station (CBS) agreed to pay the National Collegiate Athletic Association (NCAA) $6 billion over 11 years for the television rights of their men's national basketball tournament starting in 2003 (Sandomir, 1999). The National Basketball Association (NBA) has received more lucrative television contracts than the NCAA, receiving a total of $6.6 billion from Turner Network Television (TNT), American Broadcasting Company (ABC), and Entertainment and Sports Programming Network (ESPN) to cover the NBA for six seasons, starting with the 2002-03 season (NBA, 2008).

The NCAA and NBA are not the only entities making money off the popularity of basketball. Individual teams, when successful, can also enjoy many financial benefits. In 2006 George Mason University made an unlikely run to the Final Four. According to the school, it received $677.5 million in free media during the 2006 tournament (Baker, 2008). In addition, since its Final Four appearance it has seen admission inquires increase 350%, donations to their athletic club increase 52%, and season ticket sales double for the following basketball season (Baker, 2008).

In the NBA, large television contracts and bigger arenas have made franchises worth more today than ever before (NBA, 2007b). With the exception of the New York Knicks all the teams who make up the top ten in the league in overall value have made

the playoffs a minimum of two out of the last three seasons previous to this study (2005 NBA, 2005; 2006 NBA, 2006; 2007 NBA, 2007; NBA, 2007b). This suggests that the more a team wins, the more they will be worth. This motivates owners to pay players multi-million dollar contracts in hopes of compiling enough talent to win consistently. However, there are rules in both college and professional basketball limiting how much a player can be compensated for their services. This has left universities and franchises looking for additional ways to gain an advantage.

One way they have done this is through the hiring of head coaches. There is no limit on what coaches can be paid, therefore teams will often compete over those perceived as premier coaches and lure them to their team by offering them large salaries. In 2006, the average income for a coach making the NCAA Men's Basketball Tournament was $800 thousand per season. This amount rose to $1.2 million among coaches from the six Bowl Championship Series (BCS) conferences (Wieberg & Upton, 2007). In the NBA, the average coach makes $3.81 million per season and the highest paid coach for the 2007-08 season was Phil Jackson who made $10.33 million (Walker, 2007).

While universities and NBA franchises are paying coaches all-time high salaries, they expect almost instant returns from their investment. Therefore, if a coach does not win within their first three seasons, there is a high probability they will be looking for a new job (Berry, 2004). The impatience of university presidents and NBA team owners is evident by the number of coaches being fired annually. Following the 2006-07 season there were 62 Division I college basketball coaching changes among the 336 coaches, or

nearly 20 percent of all the coaches (Division, 2007). In the NBA, 9 of the 30 coaches lost their job or nearly 33 percent of all the coaches (NBA, 2007a). With coaches being given less time to prove themselves to their bosses, they are constantly trying to identify factors that will give them a competitive advantage and help them win consistently.

A common way coaches have traditionally prepared their team for upcoming opponents is through the use of video. Coaches will watch game film of their own team, trying to look for deficiencies they can improve on during practice. They also watch game film on their opponents, identifying their strengths, weaknesses, and tendencies so that they can prepare a game plan that will give their team the best opportunity to win. With modern technologies such as video editing programs, DVD burners, and internet exchange systems, watching film has never been easier or more efficient. However, because basketball schedules typically require teams to play two to four games per week there is a limited amount of time a coach can devote to watching game film. This has left coaches looking for additional tools to evaluate their team and opponents in a quick and efficient manner.

One approach commonly used is quantitative analysis of box-score statistics. Box scores provide a summary of the game by listing important statistical categories for each player who participated in the contest. These categories typically include name of player, position of player, minutes played, field goals made and attempted, three-point field goals made and attempted, free throws made and attempted, offensive rebounds, total rebounds, assists, turnovers, blocked shots, steals, personal fouls, and points. Looking at box scores at the conclusion of a game gives a coach a general sense of how his team performed in

the different statistical categories. However, if more than surface knowledge about a team is going to be acquired using box scores, it is necessary to use more sophisticated statistical analyses.

One such approach is the use of regression analysis. By analyzing box score statistics using regression analysis, studies have been able to determine which performance factors significantly contribute to the outcome of the game. Multiple studies have been conducted and they all conclude that field goal percentage is the strongest indicator of a team's win percentage (Akers, Wolff, & Buttross, 1991; Chatterjee, Campbell, & Wiseman, 1994; Onwuegbuzie, 2000). Additional findings from these studies (Akers et al., 1991; Chatterjee et al., 1994; Onwuegbuzie, 2000) support the philosophy of Dean Oliver (2004), who after statistically analyzing thousands of basketball games believes there are four critical aspects that a team must control both offensively and defensively to win the game. Those aspects are field goal percentage, offensive rebounds, turnovers, and getting to the foul line and making the foul shots. Determining which performance indicators significantly contribute to the outcome of the game can aid a coach in analyzing a game by focusing his attention on areas which impact the game most. It also serves as a starting point for additional research to be done.

Although box score statistics provide a nice summary of the game, they possess some limitations. First, basketball statistics in box scores do not always equate actual player value (Oliver, 2004). For example, a defensive player might deflect the ball causing it to fall in the hands of one of his teammates. The player that secures the ball is

credited with a steal, when in all actuality it is the player with the deflection that played the more outstanding defense and caused the steal. This is one example of many different situations throughout the course of a game where the box score does not give accurate value to the actual play or player.

Second, basketball statistics at the end of a game can be greatly influenced by the pace of play. In baseball, a game could take two hours or four hours to complete and it does not impact the statistical aspect of the game because there are equal outs for each team in every game and thus equal opportunities at success or failure (Oliver, 2004). In basketball this is not the case. For example, Team A might allow on average 75 points per game and Team B might allow 80 points per game. The normal observer might assume from the following information that Team A is a better defensive team than Team B because they allow five fewer points a game. However, when you look at a team's pace of play one might come to a different conclusion. In this same example Team A plays a slow-paced game and only averages 75 defensive possessions per game, while Team B plays a high-paced game and averages 100 defensive possessions per game. With this information you would conclude that Team B is the better defensive team because even though they allow more points per game than Team A, they do so on much more opportunities. Similar to points allowed per game, pace of play will impact all statistics found in box scores making it difficult to compare the information from game to game and team to team.

Being able to compare their team's performance from game to game and from opponent to opponent is a critical aspect of game analysis for a coach because it shows

strengths, weaknesses, and trends that can be used to design a plan to improve. Therefore to make it easier to compare basketball statistics among teams an equal possession concept has been implemented. In basketball statistics a possession starts when one team has control of the ball and ends when they lose control of the ball to their opponent. This means that a team would lose possession of the ball when they make a field goal, make a free throw that gives the other team the ball out of bounds, a defensive rebound, or a turnover. Thus an offensive rebound will not start a new possession; instead, an offensive rebound starts a new play making it possible to have multiple plays within the same possession. This distinction is necessary to keep possessions during a game equal for both teams. Recording possessions in this way controls for pace and makes it easy to compare teams or individuals against each other. (Kubatko, Oliver, Pelton, & Rosenbaum, 2007).

Analyzing box score statistics using the equal possession concept enables coaches to gain greater insight into their team and players by performing efficiency analyses. Efficiency analyses measure a statistical aspect of basketball over 100 possessions, making it possible to determine how efficient a team or individual is in a certain aspect of the game. An example of how this analysis is used can be seen in offensive efficiency ratings. On television you will routinely hear commentators refer to a team's points per game to justify whether a team is good or bad on offense. For example, a commentator might say, "Team A scores 86 points per game, giving them the best offense in the league." This statement might or might not be true, but you cannot determine this from points per game alone because this statistic is effected by pace and only tells who scores

the most points in the league. A better indication of how good a team is offensively is determined by offensive efficiency rating. This rating shows a team how many points they score per 100 possessions. Using this value controls for pace and allows one to determine how efficient a team are at scoring. Knowing a team's offensive efficiency is more useful because it reflects how a team will perform independent of game pace which gives a better indication of offensive capabilities than points scored per game. (Kubatko et al., 2007).

Efficiency analysis can be done on all aspects of the game both offensively and defensively. This information can then be used by coaches to compare their team against all other teams in the league. Being able to compare teams makes it possible to determine which teams are great, which teams are average, and which teams are poor in any statistical aspect of the game. Being able to compare their team against their opponents gives coaches a good idea of how much their team needs to improve in a certain aspect of the game to reach elite status. Such information can be very valuable for coaches when planning practices or setting team goals.

In addition to efficiency analyses, box score statistics can also be used to do percentage analyses. Percentage analyses tell a coach what percentage of all possible opportunities their team performs a specific outcome. An example of how percentage analysis can be useful is seen in rebounding. The statistic rebounds per game can be misleading; a team might average a lot of offensive rebounds because they miss an unusual amount of shots. To get a better idea of how well your team offensive rebounds within a game, a coach would want to know how many of all possible offensive

rebounding opportunities their team secured. This information is assessable by determining the team's offensive rebounding percentage. This is calculated by taking the team's offensive rebounds and dividing it by the team's offensive rebounds plus the opponent's defensive rebounds. This information can be compared against the rest of the league and a coach can determine if his team is averaging a lot of offensive rebounds per game because they perform at a superior level in this area or because they have an unusual amount of opportunities due to poor shooting.

Percentage analysis can be used for any statistic both on the offensive or defensive side of the ball. The information provided by this analysis can be used to compare one's team against one's opponent similar to efficiency analyses. However, percentage analysis is also useful because it lets a coach know immediately following a game how his/her team did in any one aspect of the game. This immediate analysis can be examined by the coach to give him/her a sense of what to look for when reviewing the game tape. The percentage analysis can also be compared from game to game to give the coach a sense of the progression or digression of their team in a certain area over the course of the season. Such information can enable a coach to make adjustments to practice plans through the course of a season if they notice that their team has struggled in a particular area over an extended amount of games.

While box score statistical analyses can provide coaches with valuable information on how his/her team is performing in certain aspects of the game, the information that can be gained from these analyses are limited in their depth. For example, box score statistical analyses can tell a coach his/her team's offensive efficiency

rating, but it gives no insight into why a team's offensive rating is what it is or how a team's offensive rating can be improved. In order to gain answers to these questions it is necessary for a team to chart their games. A team can chart any aspect of the game in which they want to gain a deeper understanding.

An example of how game charting can give a coach a deeper understanding of his/her team's offensive rating is seen in a study designed to measure the productivity of the Sacramento Kings' players on different types of offensive plays (Peterson, 2005). The study categorized every type of offensive play one would encounter during the course of a game and then measured the productivity of each player for each individual offensive play. Charting this information allows a coach to see how efficient each of his/her players and team are at every kind of offensive play. This sheds some light on why his/her team's offensive rating is what it is and the coach can begin to design adjustments that will better meet the players' offensive strengths.

Adding the information gained from box score analyses and game charting to the information gained by watching film provides a coach with abundantly more information about his/her team and their opponents than watching film alone. This added information gives a coach a competitive advantage over his/her counterpart who only utilizes video to prepare for a game, because the additional information can help him/her better prepare his/her team for the game and increase his/her likelihood of success.

However, one problem with basketball statistical research and game charting is that the field is relatively narrow. In nearly every aspect of basketball statistical research and game charting there are more studies done on the NBA than on college basketball.

This might be because there are far fewer teams in the NBA with more extensive coverage making it easier to retrieve data and examine the entire population. This has left a limited amount of public research of this kind done on college basketball. This is a problem because the college game and professional game is very different, which can make it difficult to transfer the findings of the professional game to the college game. Therefore, it would benefit college basketball coaches if more statistical research and game charting research were focused on college basketball.

Since studies using box scores (Akers et al., 1991; Chatterjee et al., 1994; Onwuegbuzie, 2000) have supported the philosophy held by Oliver (2004) that there are four critical aspects to winning a game, namely field goal percentage, offensive rebounds, turnovers, and getting to the foul line and making the foul shots once the team is there, it would seem to be most beneficial to college coaches if more information was gained on how to improve in these areas.

Since the Oliver (2004) philosophy on how to win a game is based on outcomes, it would benefit coaches if research was done examining what occurred during the actual playing of the game that leads to greater efficiency in these outcomes. A study was done on the NBA that involved game charting the number of touches per possession and dribbles to end a possession's effect on points per possession (Game, 2008b). This enabled data to be collected on how touches per possession and dribbles to end a possession affected the most important element of offensive efficiency, points per possession. It also enabled additional information to be gathered on factors that affect points per possession such as field goal percentage, turnovers, and fouls.

The study (Game, 2008b) gives coaches a better idea of what is transpiring during the course of a game that leads to an efficient achievement of the outcome based suggestions made by Oliver (2004). With this type of information inferences can be made on what type of offensive activity (multiple passes, multiple dribbles, or a combination of both) leads to the most efficient results in the area's deemed critical to winning (Oliver, 2004). With multiple offensive systems available, some emphasizing the pass and some emphasizing the dribble, this could serve as valuable information for coaches trying to determine which type of offensive system to choose for their team. It could also serve as a tool for coaches to determine if their current offensive system is the best choice for their team.

Since there is no study of this nature done on college basketball, it would be beneficial for coaches if one was completed and made public. In doing so one could follow the model created by the study done on the NBA (Game, 2008b). However, it would also be helpful to coaches if post touches were charted in addition to touches and dribbles-to-end-a-play (DEP) because this will allow the coaches to see the impact post players have on scoring efficiency.

It would also be beneficial to coaches if the elements examined in the NBA study (Game, 2008b) were evaluated based on plays as opposed to possessions. This is because possessions do not end with an offensive rebound (Kubatko et al., 2007), which has the potential to skew data towards high amounts of touches when an offensive rebound is passed out to the perimeter in an attempt to start a new offensive sequence. This problem can be solved by tracking plays instead of possessions because when an offensive

rebound is passed out to the perimeter to start a new offensive sequence this will also start a new play. This allows the results to more realistically represent what strategies (touches or dribbles) teams are implementing in an attempt to score.

After talking with a Division I men's basketball coaching staff it was felt that adding elements neglected by the study on the NBA (Game, 2008b) would provide empirical evidence on anecdotal theories held by coaches concerning ball movement, dribbles, and post touches. Therefore, the primary purpose of this study will be to use game charting techniques to evaluate the effects touches per play, post touches per play, and DEP have on points per play. Secondary purposes will be to evaluate the effects touches per play, post touches per play, and DEP have on field goal percentage, turnovers, and fouls.

Null Hypotheses

1. Touches per play, post touches per play, and DEP will have no significant effect on points per play.
2. Touches per play, post touches per play, and DEP will have no significant effect on field goal percentage.
3. Touches per play, post touches per play, and DEP will have no significant effect on turnovers.
4. Touches per play, post touches per play, and DEP will have no significant effect on fouls.

Definition of Terms

Dribble-to-end-a-play (DEP) – the total number of dribbles will be counted for the player who terminates the play (i.e., made field goal, foul, turnover, deflection out of bounds) within scoring position.

Efficiency analysis – measures a statistical aspect of basketball over 100 possessions.

Percentage analysis – measures what percentage of all possible opportunities a team performs a specific outcome.

Play – the sequence between the first touch within scoring position (within 25 feet of the basket) and the action ending the play which could include made field goal, common foul, turnover, defensive rebound, deflection out of bounds, made free throw, or offensive rebound. An offensive rebound will only end the play if the offensive rebounder passes the ball to another player to restart the offense. If a player who secures the offensive rebound immediately goes back up with a shot it will count as a continuation of the original play.

Post area – within 8 feet of the basket.

Post touch – each time a player touches the ball with his back to the basket within the post area.

Scoring position – within 25 feet of the basket.

Touch – each time a player touches the ball within scoring position.

Delimitations

1. The study will only evaluate the Brigham Young University men's basketball team and their opponents for the 2006-07 and 2007-08 seasons.
2. The study will only evaluate touches, post touches, and DEP that occur in a half-court setting.

Assumptions

1. A realistic offensive scoring position is within 25 feet of the basket.
2. The post area is within 8 feet of the basket.

Limitations

1. There will be some subjectivity by the researcher in determining realistic scoring position, post area, and assists.

Chapter 2

Review of Literature

History

Dr. Luther H. Gullick, head of the physical training department of the International Training School of the Young Men's Christian Association in Springfield, Massachusetts, had a problem with boys in the school becoming troublesome during the winter months. Being relegated indoors, instructors taught traditional indoor activities they had brought over from England. These included activities such as gymnastics, calisthenics, and marching drills. The boys would quickly become disinterested in the activities and start to make trouble for their instructors. This led Dr. Gullick in 1891 to ask instructor James Naismith to create a new game that would better hold boys' attention during the winter months (Fox, 1974). Naismith took aspects from different sports he was familiar with such as football, rugby, soccer, water polo, field hockey and lacrosse and created a game that required a team to put a ball through a horizontal goal that was elevated above the ground (Isaacs, 1984).

This game would become known as basketball and it did not take long for the sport to spread across the country and the world. Naismith introduced basketball to his students just before Christmas vacation in 1891. During Christmas vacation many of his students introduced the game in their home towns and in January of 1892 the original 13 rules of basketball were published in the school newspaper, the *Triangle*, which was distributed to YMCAs throughout the world (Fox, 1974). Later that month, on January 20, 1892 the first basketball game was played at the International Training School of the

Young Men's Christian Association and less than two months later on March 11, 1892 the first public game was played at the school between the instructors and students (NCAA, 2007).

Growth of Basketball

Within a couple years basketball was not just being played in local YMCAs, the sport had spread to the college and professional ranks. The first half of the 20th century was a time in which basketball became much more structured. Many rules were added and altered to Naismith's original 13 to give the game a quicker pace and better flow which made it more enjoyable for spectators to watch (Fox, 1974; NCAA, 2007). Conferences were formed in the college game which added to the excitement of the game by creating rivalries and paving the way for conference and national tournaments (Isaacs, 1984; Satter, 2003).

In the professional game there was numerous professional basketball leagues created during the first half of the 20th century. A majority of these leagues failed because of financial difficulties caused by competition between multiple leagues, two World Wars, the Great Depression, and a dance hall legacy that limited the amount of paying spectators that could watch the games. Despite these difficulties, following World War II two professional basketball leagues had emerged, the Basketball Association of America with a predominant number of its teams on the east coast and the National League centered in the Midwest. However, by the end of the 1940s the National League was experiencing financial troubles so the league merged with the Basketball Association of America in 1949 forming the NBA (Fox, 1974).

Heading into the second half of the 20th century both college and professional basketball benefited from having single leagues that faced little in the way of competition. Until 1952, the National Invitation Tournament (NIT) and NCAA basketball tournaments competed for colleges' best teams, with some of the best teams competing in both tournaments. This made it impossible to determine who the outright national champion was. However, in 1952 the NCAA tournament supplanted the NIT tournament as the most prestigious collegiate tournament in the country and every year since the winner of the NCAA tournament has been declared the outright national champion in college basketball (Isaacs, 1984; Satter, 2003). Having the NCAA tournament determine the national champion in college basketball has created a single elimination format filled with emotion and drama that is very attractive for fans and has made the NCAA men's basketball tournament one of the major sporting events in America. This is evident by CBS's agreement to pay the NCAA $6 billion for the television rights of the men's basketball tournament for 11 years starting with the 2003 tournament. When the agreement was announced Sean McManus, president of CBS sports said, "There is no more important event at CBS, not just CBS Sports, than the men's basketball championship" (Sandomir, 1999).

In professional basketball, the NBA has been the premier professional basketball league in the world since its creation in 1949. It had competition briefly from 1967-1976 with the creation of the American Basketball Association (ABA), but even during that time the NBA had the superior teams and a majority of the superior players, leading the ABA to disband as a league and the NBA adopting four of the ABA's franchises (Denver

Nuggets, Indiana Pacers, New York Nets, and San Antonio Spurs). With the ABA folding after the 1976 season, the NBA no longer had competition for fans of professional basketball and this enabled the league to prosper. The league saw a big increase in attendance during the 1980s and 1990s (NBA, 1999) with the development of stars in big markets such as Magic Johnson, Larry Bird, and Michael Jordan. With growing popularity the NBA was able to cash in on lucrative television contracts with TNT, ABC, and ESPN totaling $6.6 billion for six seasons starting with the 2002-03 season (NBA, 2008).

Big Business Basketball

Basketball has come a long way from its humble beginnings, transforming into a big business at both the college and professional levels. It was already mentioned how lucrative the men's basketball tournament is for the NCAA; however, being successful in basketball also benefits individual schools as well. In 2006 George Mason University made an unlikely run in the NCAA tournament making it to the final four. According to the school since its final four run, admission inquires to the school have increased 350%, out of state applications increased 40%, active alumni increased 25%, their athletic website increased viewers by 503%, Patriot Club fundraising increased 52%, season ticket sales doubled for the following basketball season, and they received an estimated $677.5 million in free media during the 2006 NCAA tournament (Baker, 2008).

Another school that shows the impact success in basketball can bring is Gonzaga. Gonzaga is a small private school in Washington that was most likely unknown to most of the country until 1999 when the school made a magical run to the elite eight of the

NCAA tournament. The following two seasons Gonzaga made it to the sweet sixteen and have made the NCAA tournament every year since. According to the school, admission inquires per year and total enrollment has more than doubled since 1999, including attracting students from the east coast, a rarity before their NCAA elite eight appearance (Potter, 2008).

Similar to college basketball, the NBA has also seen their product turn into a multi-billion dollar business. With large television contracts and bigger arenas NBA franchises are worth more money today than they ever have been before with a majority of the franchises being worth over $300 million (NBA, 2007b). With a few exceptions, the more a team wins the more their franchise is worth (NBA, 2007b). This motivates owners to put together the best team possible. The monetary success of the NBA has benefited the players, as teams are willing to pay players large amounts of money in hopes of collecting enough talent to win consistently and increase the value of their franchise. For the 2007-08 season the top nine players in the NBA were all making in excess of $19 million per season (NBA, 2007-08).

Because of rules in both college and professional basketball there is a limit to how much a player can be compensated for their services. This has left teams looking for additional ways to gain an advantage. One place universities and franchises have looked to gain that competitive advantage is in the hiring of head coaches. Teams hope to hire the best coach possible, knowing that a good coach will have positive impacts upon the success of a team, while a poor coach will have the opposite effect. Since there is no limit on what coaches can be paid teams are often competing over those coaches who are

perceived as the top in their profession. This competition has greatly increased the salaries of coaches. In the NBA, the highest paid coach for the 2007-08 season was Phil Jackson who made $10.33 million, while the average NBA coach makes $3.81 million per season (Walker, 2007). In college, the average income for coaches making the 2006 NCAA tournament was $800 thousand, but if you look at the coaches in the six BCS conferences that figure raises to $1.2 million and this figure does not include the hundreds of thousands of dollars more popular college coaches make from outside sources such as shoe deals and speaking engagements (Wieberg & Upton, 2007).

The financial benefits that come to universities and franchises that win have led teams to pay all-time high salaries to coaches, but with the increase in pay come an increase in expectations. Universities and franchises want almost instant returns on their investment and so if the coach does not win they can expect to be looking for a new job within a few seasons (Berry, 2004). University athletic directors' and NBA team owners' impatience is characterized by the number of firings seen among the coaching profession each year. After the 2006-07 season there were 62 Division I college basketball coaching changes among the 336 coaches, or nearly 20 percent of all the coaches (Division, 2007). In the NBA, 9 of the 30 coaches lost their job or nearly 33 percent of all the coaches (NBA, 2007a).

With coaches being given less time to prove themselves to their superiors, they are constantly trying to identify factors that will give them a competitive advantage and help them win consistently. One way coaches try to identify factors that will give them an edge is through scouting, either self-scouting or through scouting of their opponent.

The most common way to scout is through the use of video. Coaches will study game tape on their opponents in order to create game plans designed to exploit their weaknesses and limit their strengths. They also watch game film on their own team in order to develop strategies that will take advantage of their strengths and minimize their weaknesses. This creates a cat and mouse game with coaches making adjustments in order to try and gain an advantage over their opponent. Modern technology such as video editing programs, DVD burners, and internet exchange systems have made watching game film easier and more efficient. Despite these resources, basketball schedules typically require teams to play two to four games a week, which leaves a limited amount of time available to devote to watching game film. This has left coaches looking for additional tools to evaluate their own team and their opponents in a quick and efficient manner.

Statistical Approach to Basketball

One approach which was pioneered by baseball experts and now being implemented into basketball is the use of quantitative analysis of game statistics. A reason baseball has been the leader in quantitative analyses of sport is because the game is suitable for statistical analysis. In baseball, the nine players on the field have very limited influence over each other making it far easier to use statistics to show the value each individual player contributes to the team as a whole. Basketball is a little more complex because there is more interplay between basketball players during the course of a game making it more difficult to apply statistical values to actual player value (Oliver, 2004). For example, a defensive player might deflect the ball causing it to fall in the

hands of one of his teammates. The player that secures the ball is credited with a steal, however in all actuality it is the player that had the deflection that caused the steal. Therefore, the player who played the more outstanding defense and caused the steal does not receive credit for it in the stat sheet at the end of the game. This is an example of one of the many different situations throughout the course of a basketball game where the stat sheet might not give accurate value to the actual play or player.

In addition, basketball can be greatly influenced by pace of play. In baseball, a game could take two hours or four hours to complete and it does not impact the statistical aspect of the game because there are equal outs for each team in every game and thus equal opportunities at success or failure. In basketball this is not the case. A basketball team's pace can greatly alter what their statistics look like at the end of a game making it difficult to compare teams with different styles (Oliver, 2004). For example, Team A might allow on average 75 points per game and Team B might allow 80 points per game. The normal observer might assume from the following information that Team A is a better defensive team than Team B because they allow five fewer points a game than Team B does. However, when you look at a team's pace of play one might come to a different conclusion. In this same example Team A plays a slow-paced game and only averages 75 defensive possessions per game, while Team B plays a high-paced game and averages 100 defensive possessions per game. With this information you would conclude that Team B is the better defensive team because even though they allow more points per game than Team A they do so on much more opportunities.

Equal Possession Concept

These reasons might influence some people to conclude that little valuable information can come from basketball game statistics. However, basketball statisticians have implemented some statistical concepts that make it possible for valuable information to be had from basketball game statistics. The most basic concept to understand when analyzing basketball is the possession concept, specifically the concept of equal possessions for each team in a game. In basketball statistics the definition of a possession is the time from when one team has control of the ball until the time that team loses control of the ball. This means that a team would lose possession of the ball when they make a field-goal, make a free-throw that gives the other team the ball out of bounds, defensive rebound, or a turnover. Thus an offensive rebound will not start a new possession; instead an offensive rebound starts a new play making it possible to have multiple plays within the same possession. This distinction is necessary to keep possessions during a game equal for both teams (Kubatko et al., 2007).

Recording possessions in this way assures that the two teams will have approximately the same amount of possessions per game, similar to baseball where teams have an equal number of outs. Ensuring that teams have an equal number of possessions makes it possible compare teams or individuals on an equal basis (Kubatko et al., 2007).

Possessions can be determined one of two ways. The first and most accurate way is to count possessions using the play-by-play game logs. However, determining possessions this way is very tedious and time consuming. Therefore, in order to determine possessions in a timely manner they can be estimated using information from

the game's box score. Listed below are some of the most commonly used formulas to determine total possessions from a box score:

POSS=FGA-OREB+TO+0.4*FTA (Oliver, 2004)

POSS=FGA-OREB+TO+0.44*FTA (Kubatko et al., 2007)

POSS=FGA-OREB+TO+0.475*FTA (Pomeroy, 2005).

All of these formulas are exactly the same except for the decimal preceding free throw attempts. The decimal represents what percentage of free throw attempts end possessions (Oliver, 2004). The originators of these formulas have all examined numerous game-by-game play logs to come to this conclusion and a possible reason that the numbers differ slightly is because of the sample they drew from. The studies of Oliver (2004) and Kubatko et al. (2007) analyze NBA games, where Pomeroy (2005) deals primarily with college basketball games.

Problem with Basketball Statistical Field

Although it can be explained why the possession formulas differ slightly, it does raise a problem that exists in the basketball statistical world. Anyone can go into a library and find shelves and shelves of books about different basketball philosophies, drills, and techniques. However, it is far more difficult to find books that explain the different concepts and terminology associated with analyzing basketball statistics. This is because the field of analyzing basketball statistics was born out of non academic sources, which has led to a smorgasbord of different concepts and terminology used to describe similar ideas (Kubatko et al., 2007). Such a problem can leave people, especially those

new to the field, confused as to what concepts to use and what is the proper name for those concepts.

However, recently there has been a peer-reviewed article published by four of the leaders in the field (Justin Kubatko, Kevin Pelton, Dean Oliver, and Dan Rosenbaum) that has attempted to wade through all the different concepts and terminology associated with basketball statistics and provide a basis of knowledge that future statistical research in basketball can be based from (Kubatko et al., 2007). This is a step in the right direction that will hopefully inspire others in the field to publish their findings in an attempt to bring more academic credibility to the field. However, until more people publish their findings the primary source for finding information on analyzing basketball statistics can be found on Web sites such as 82games.com, sonicscentral.com/apbrmetrics, and kenpom.com. While the articles on these Web sites do not have to pass the rigors that articles for peer-reviewed publications do, a majority of the articles are from proven individuals in the field and can be trusted.

Box-Score Statistics

Regression analysis. There have been numerous statistical analyses done on basketball using box scores that can give coaches valuable information. These different analyses can be divided into four categories: regression analysis, efficiency analysis, percentage analysis, and other. There have been a few different regression analyses done both in the NBA and college looking at how box score statistics are related to winning. Of the studies done they all concluded that field goal percentage is the strongest indicator of winning percentage (Akers et al., 1991; Chatterjee et al., 1994; Onwuegbuzie, 2000).

In addition to field goal percentage, regression analyses have also suggested that rebounding (Akers et al., 1991; Chatterjee et al., 1994; Onwuegbuzie, 2000), turnovers (Akers et al., 1991; Chatterjee et al., 1994), free throw percentage (Chatterjee et al., 1994), assists (Onwuegbuzie, 2000) and personal fouls (Akers et al., 1991) all play a significant role in determining the winner.

The findings of these analyses align with the philosophy of Dean Oliver (2004), who after analyzing thousands of basketball games has suggested that there are four critical aspects that a team must control both offensively and defensively to win the game. These four aspects are field goal percentage, offensive rebounds, turnovers, and getting to the foul line and making the free throws. The study's conclusions might seem like common sense but, it is important to determine what statistics do in fact significantly affect the outcome of the game because it can help coaches and basketball statisticians determine what aspects of the game should be examined in greater detail.

Efficiency analysis. Using box score statistics has also enabled basketball statisticians to do efficiency analyses on teams and individuals. Efficiency analyses measures a statistical aspect of basketball over 100 possessions. This makes it possible to determine how efficient a team or individual is in a certain aspect of basketball. An example of how this analysis is used can be seen in offensive efficiency ratings. On television you will routinely hear commentators refer to a team's points per game to justify whether a team is good or bad on offense. For example, a commentator might say, "Team A scores 86 points per game, giving them the best offense in the league." This statement might or might not be true, but you cannot determine this from points per game

alone because this statistic is affected by pace and only tells who scores the most points in the league. A better indication of how good a team is offensively is determined by the offensive efficiency rating. This rating shows a team how many points they score per 100 possessions. Using this value controls for pace and allows one to determine how efficient a team are at scoring. Knowing a team's offensive efficiency is more useful because it reflects how a team will perform independent of game pace which gives a better indication of offensive capabilities than points scored per game. (Kubatko et al., 2007).

Efficiency analysis can be done on all aspects of the game both offensively and defensively. This analysis not only tells a team how efficient they are in a certain aspect of the game, but is also allows a team to see how they compare against all the other teams in the league. Being able to compare teams makes it possible to determine which teams are great, which teams are average, and which teams are poor in any statistical aspect of the game. Being able to compare their team against the rest of the teams in the league also gives the coaches a good idea of how much their team needs to improve in a certain aspect of the game to reach elite status. Such information can be very valuable for coaches when planning practices or setting team goals.

Percentage analysis. Another form of analysis that lets a coach know how good they are in a certain aspect of the game is percentage analysis. Percentage analysis tells a coach what percentage of all possible opportunities their team performs a specific outcome. An example of how percentage analysis can be useful is seen in rebounding. The statistic for rebounds per game can be misleading; a team might average a lot of

offensive rebounds because they miss an unusual amount of shots. To get a better idea of how well your team offensive rebounds within a game, a coach would want to know how many of all the possible offensive rebounding opportunities did their team secure. This information is assessable by determining the team's offensive rebounding percentage. This is calculated by taking the team's offensive rebounds and dividing it by the team's offensive rebounds plus the opponent's defensive rebounds. This information can be compared against the rest of the league and a coach can determine if his/her team is averaging a lot of offensive rebounds per game because they perform at a superior level in this area or because they have an unusual amount of opportunities due to poor shooting.

Percentage analysis can be used for any statistic both on the offensive or defensive side of the ball. The information provided by this analysis can be used to compare one's team against one's opponent similar to efficiency analyses. However, percentage analysis is also useful because it lets a coach know immediately following a game how his/her team did in any one aspect of the game. This immediate analysis can be examined by the coach to give him/her a sense of what to look for when reviewing the game tape. The percentage analysis can also be compared from game to game to give the coach a sense of the progression or digression of their team in a certain area over the course of the season. Such information can enable a coach to make adjustments to practice plans through the course of a season if they notice that their team has struggled in a particular area over an extended amount of games.

Other box score statistical studies. In addition to the analyses mentioned above there have been other statistical analyses done to assist coaches in identifying factors that will help coaches win consistently. One such analysis has been to look at the impact playing at home has on the outcome of the game. Of four major American sports (hockey, baseball, football, and basketball), basketball had the largest home court advantage with home teams winning approximately 64% of their games. This was compared to 61% for hockey, 57% for football, and 53% for baseball (Courneya & Carton, 1992). More research is needed to understand why basketball enjoys more of a home court advantage than the other sports, but some reasons could include the close proximity of the crowd, the noise level of the crowd, the effect different backdrops have on opponent's shooting, and the number of foul calls by officials for home teams versus visiting teams.

To better understand the advantage home teams enjoy there has been a study done on the NBA to examine when during the course of a game the home team enjoys its biggest advantage. According to the study, NBA teams average a 3.5 point advantage at home. However, the results of the study conclude that approximately two-thirds of a team's home court advantage is experienced in the first quarter and the advantage decreases in every succeeding quarter (Jones, 2007). This is valuable information for a coach to know when preparing their game plan for a game on the road. If they can design a plan to sustain the first quarter they know they have eliminated the largest portion of the home court advantage.

A study has also used box scores to determine how different position skills contribute to winning (Page, Fellingham, & Reese, 2007). The study concluded that for all five positions having more offensive rebounds, more assists, shooting a higher percentage, and committing fewer turnovers than their positional opponent increased the point spread of the game (Page et al., 2007). These results align with common sense; however, some of the other results were more surprising. For example, defensive rebounding by centers and forwards appear to have little effect upon the point-spread of a game, but defensive rebounding by guards significantly impacts the outcome of the game (Page et al., 2007). Also, assists and turnovers from the small forward have the largest positive impact and the largest negative impact upon the outcome of the game (Page et al., 2007). While more research will be needed to determine why these results are what they are, it hints at how important athletic, skilled small forwards have become in the NBA game today.

Having a knowledge of the quantitative value of skills for the different positions and the effect those skills have on the outcome of the game is helpful information for a coach when designing the skill development section of practice. The coach can focus on specific skills for specific positions that will have the greatest impact on the game. The information can also be used when an organization is trying to decide what type of players they want to sign to their team (Page et al., 2007).

In addition to applying quantitative values to individual positions, analysis has also been done on five man units as a whole. On 82games.com there is a list of the NBA's top 5 man combinations as determined by point differential (Sortable, 2008).

Knowing which player combinations produce the most positive results for a team is important information for a coach to consider when establishing their player rotations. Taking that information into consideration can help a coach assure that the most productive five-man unit is on the court during the most crucial times of the game.

Box score statistics, when analyzed correctly, can provide coaches with valuable information to help them in the decision process. This is why so many different studies and analyses using box scores have been done. However, basketball studies are not limited to using box-scores. There has been a study done examining the decision of whether to foul or play defense on the last possession of a game when your team is leading by three points. According to the study, when team's foul immediately they win ten percent more games than teams that play defense on the final possession (Annis, 2006). This is just an example of how statistical analysis outside of box scores can be used by coaches when deciding what strategy to implement within the course of the game.

Game Charting

Another brand of research designed to give coaches a deeper understanding of what is going on during the course of the game is known as game charting. Through game charting a team can gain a deeper understanding of what is happening than through box scores alone. For example, studies using box scores have concluded that field goal percentage is the best indicator of winning percentage (Akers et al., 1991; Chatterjee et al., 1994; Onwuegbuzie, 2000). Analyses can be run using box scores to determine how efficient teams are on offense. This gives a sense of which team is more likely to shoot a

higher percentage and be more likely to win the game. However, this information does not give any hints on how a team can improve their offensive efficiency and thus increase their likelihood of winning. Such information would be important for any coach trying to improve their team and it can be obtained through game charting.

An example of how game charting can help coaches gain a deeper understanding of their team's offensive efficiency is seen in a study designed to measure the productivity of the Sacramento Kings' players on different types of offensive plays (Peterson, 2005). The study categorized every type of offensive play one would encounter during the course of a game and then measured the productivity of each player for each individual offensive play type. Productivity was measured by a combination of field goals made, field goals attempted, effective field goal percentage, free throws made, free throws attempted, turnovers, and points (Peterson, 2005).

Charting this information allows a coach to see how efficient each of his/her players and team as a whole are at every different kind of offensive play. This helps a coach understand why his/her team is or is not efficient on offense and can help the coach make the necessary adjustments to their offensive scheme in order to meet the strengths of the players and hopefully increase the efficiency of their offense. It also gives the coach the ability to show a player how they are performing in the different types of offensive plays. The player can then use that information to improve during the off-season.

In addition to charting offensive play productivity, a team can also chart the efficiency of their team from different locations on the floor (Game, 2008a). This allows

a coach to examine the different spots on the floor and determine from which spots their team shoots the best, gets fouled the most, and where they have the most turnovers. This allows the coach to design plays that put his team in the most efficient spots on the floor to score.

This game charting could also be used for individual players. Knowing what percentage a player shoots from each spot on the floor would be valuable information for a player because he/she could analyze where he/she shoots best on the floor and then work to improve on areas where he/she is weakest. Also, similar to the idea that a coach knows the free throw percentages of all his/her players so that he/she can put his best free throw shooters on the floor when his/her team has a lead at the end of a game and it is likely that their team is going to be fouled. The coach would now know what percentages each of his/her players shoot from the different spots on the floor and if the team needed a basket at the end of the game the coach could design a play for a player to get a shot in an area of the floor that he shoots the highest percentage. In doing this the coach increases the likelihood of his/her player making the basket.

The more game charting a team does, the more information a coach will have about his/her team. For example, another study was done examining how the number of touches and dribbles impacts the effectiveness of an offense (Game, 2008b). From this information it can be determined if there is a range of touches or dribbles that produces the most efficient type of offense. This can be valuable information because there are many different types of offenses with some emphasizing the dribble and some

emphasizing the pass. Having data on what your team does best could influence a coach on what type of offense to implement with their team.

Combining information gathered from video, statistics, and game charting provides a coach with abundantly more information than watching video alone. This added information can be a valuable asset to coaches as they look for ways to gain a competitive advantage over their opponents. However, one problem with statistical research and game charting research is that it requires money and man power to produce. This might make the process too costly for some colleges to support. This reason coupled with far fewer teams in the NBA and more extensive coverage making it easier to retrieve data on the entire population might be an explanation as to why there are numerous more studies of these nature on the NBA than on college basketball.

The limited amount of information of this kind on college basketball is a problem because the college game is so different from the NBA making it difficult to transfer findings from studies done on the NBA to the college game. Therefore, any public studies done using statistics or game charting to analyze college basketball would serve as a benefit for the game and its coaches as they look for deeper understandings of the game in hopes of gaining an advantage for their team.

Chapter 3

Methods

Design

This study will collect and evaluate data on game film from Brigham Young University men's basketball team for the 2006-07 and 2007-08 seasons. A Bayesian hierarchical model will be used to statistically analyze the data from this study in order to evaluate the effect touches per play, post touches per play, and DEP have on points per play, field goal percentage, turnovers, and fouls for men's Division I college basketball.

Game Film

The game film viewed for this study will include all 68 games Brigham Young University men's basketball team played against Division I opponents during the regular and post season over the 2006-07 and 2007-08 seasons. This excludes Brigham Young University's game against Western Oregon during the 2006-07 season because Western Oregon is a Division II school. The reason for eliminating this game from the data source is because of the discrepancy in talent among the two divisions. The discrepancy in talent might lead to unusual performance outcomes that could skew the data unrealistically.

Pilot Data

Pilot data were collected on three Division I men's college basketball games. The purpose of the pilot data was to refine methodology and determine the amount of games on which to collect data. From the pilot study it was determined that data would be manually collected on a score sheet for play number, touches, post touches, DEP,

assists, offensive rebounds, the play's outcome, and the amount of points the play produced. From the pilot data it was also estimated that a typical Division I men's basketball game consists of 60-80 plays per team for a total of 120-160 plays per game. It was also determined from the pilot data that it takes between 60-90 minutes to chart a game. Therefore, it is estimated that it will take approximately 100 hours to chart all 68 games and there will be data collected on approximately 10,000 plays.

Procedures

The study will utilize game film from Brigham Young University men's basketball 2006-07 and 2007-08 seasons. Each game played during those two seasons will be viewed and game charted by a researcher. The researcher will chart play numbers, touches, post touches, DEP, assists, offensive rebounds, outcomes, and points for each offensive play during the course of the game (see Figure 1). The data collected on the two teams for each game will be separated and organized onto two spreadsheets making it possible to decipher between Brigham Young University's offensive plays and their opponent's offensive plays.

Play #	Touches	Post Touches	Dribbles	Assist	Offensive Rebound	Outcome	Points
1	12	2	3	N	N	Foul	1
2	7	0	2	N	N	TO	0
3	2	0	3	N	N	2 make	2
4	2	0	4	N	Y	2 miss	0
5	2	0	0	Y	N	2 make	2
6	6	0	2	N	N	3 miss	0
7	2	0	5	N	N	2 make	2
8	2	0	3	N	N	2 miss	0
9	4	1	1	Y	N	2 make	2
10	4	1	6	N	N	TO	0

Each team's offensive plays will be assigned a number in numerical order. The play number will coincide with the numerical order that the play occurred in the game. For example, Brigham Young University's first offensive play of the game will be assigned play number one and every subsequent play will be assigned its appropriate number following numerical order. The same sequence will be followed for the opponent's offensive plays. The identical play numbers for the two teams playing in the game will not be confused because each team's data will be collected and organized on separate spreadsheets.

For the purposes of the study, it needed to be determined if data would be charted according to possessions or plays. Although possessions are desirable because they are relatively equal for both teams, it was felt that plays would be more appropriate for this study. This is because possessions can result in multiple plays as a result of offensive rebounds. It was felt this could skew the data unrealistically towards large counts of touches and post touches since offensive rebounds are often passed back out to the perimeter in order to start a new offensive sequence. Therefore it was felt that using plays would better represent what strategies teams were trying to implore in order to score.

It was also determined that only half-court offensive plays will be examined. This is in order to eliminate transition baskets which usually requires few passes and primarily results in lay-ups or uncontested shots which might skew the data for plays involving few touches. During this study, a transition play will be any occurrence where the offense has more players in scoring position than the defense has defenders.

Offensive plays will also only be counted if they originate from a realistic scoring position, which for this study will be within 25 feet of the basket. This eliminates fluke plays such as a player making a shot from behind half-court.

Every play will begin with the first touch that occurs within scoring position. The following activities will constitute the end of a play, made field goal, common foul, turnover, defensive rebound, or deflection out of bounds. If the play results in a shooting foul then the play will conclude with the making of the final free throw or the rebound of a missed free throw and the points from the free throws will be attributed to the possession in which the shooting foul occurred. In the case of offensive rebounds, if the player who secures the offensive rebound immediately goes back up for a shot then it will be counted as a continuation of the original play, thus eliminating multiple one possession plays that would unrealistically skew data for single touch plays. However, if the offensive rebounder passes the ball out to another player in an attempt to restart the offense, than a new play will be counted starting with the touch of the player restarting the offense.

Touches will only be counted when they occur within a realistic offensive scoring position. The first touch can be as a result of a player dribbling the ball into scoring position or as a result of a player passing the ball into scoring position. This eliminates touches that might occur before a team reaches scoring position such as outlet passes, passes to defeat a defensive press, or any other situation that might warrant additional touches before reaching scoring position. Also, each time a player touches the ball within scoring position it is counted as a touch. For example, if a play sequence was Johnson,

Clark, Brown, Clark, it would count as four touches. In the instance when a team is taking the ball out of bounds within scoring position than the player passing the ball in bounds is counted as the first touch. For example, if Jones was taking the ball out of bounds under his team's basket and passed it to Matthews who immediately took a shot, it would count as two touches. This was determined because it is possible to record an assist as an in-bound passer.

Post touches will be counted each time a player touches the ball with his back towards the basket within the offensive post area. The offensive post area will be considered anywhere within 8 feet of the basket. Stipulating that a player must originally have his back towards the basket eliminated post touches that might occur as a result of a player driving to the basket and passing to a teammate in the post area for a lay-up. In the researcher's mind that situation constitutes more as a touch then a post touch because the result of the play was primarily determined by the driving player and therefore does not require the defense to adjust to the post player's touch which is the effect of a post touch that is trying to be examined in this study. It should also be noted that it is not necessary for a player to be a post player to record a post touch.

The total number of dribbles by the player who terminates the play will be counted. Again, only dribbles that occur within scoring position will be counted. This eliminates all dribbles that take place behind half-court in order to advance the ball into scoring position. It also eliminates a play where a player dribbles the ball off his foot out of bounds behind half-court or any other similar play.

Assists and offensive rebounds will be determined by the subjectivity of the researcher following the guidelines established for each statistical category by the NCAA for college basketball.

In the outcome column will be a description of how the play concluded. The following outcomes are possible: 2 make, 2 miss, 3 make, 3 miss, 2 make + foul, 3 make + foul, foul, turnover, and deflection out of bounds. The point's column will list how many points were scored on that play.

Data Sources

Previous to this study, video from each game played by Brigham Young University during the 2006-07 and 2007-08 seasons was digitally captured into video editing software called DV Sport (DV Sport Inc., Pittsburgh, PA). Then using DV Sport, Brigham Young University men's basketball video coordinators edited each game, separating Brigham Young University's offensive possessions from their opponent's offensive possessions. During this process each offensive possession for each team was automatically coded using numbers in numerical order that coincide with the order that possession occurred in the game. Therefore each team's first offensive possession would be coded number one.

Each offensive possession for Brigham Young University and their Division I opponents from the 2006-07 and 2007-08 seasons will be viewed and broken down into plays using DV Sport software and game charted manually using a score sheet. The score sheet will consist of the following categories: play number, touches, post touches, dribbles, assist, offensive rebound, outcome, points (see Figure 1). After manually

recording the data from the game on a score sheet the information will be transferred to a Microsoft Excel spreadsheet that is similar to the score sheet used to manually record the data (see Figure 2). The reason for transferring the information to an electronic format is to make it easier to input the data for statistical analysis.

Scout Team	Opponent	Home Team	Date	Play #	Touches	Post Touches	Dribbles	Assist	Offensive Rebound	Outcome	Points
BYU	AFA	BYU	1-3-06	1	7	1	0	Y	N	2 make	2
BYU	AFA	BYU	1-3-06	2	3	0	3	N	N	3 miss	0
BYU	AFA	BYU	1-3-06	3	6	1	1	N	Y	2 make	2
BYU	AFA	BYU	1-3-06	4	1	0	2	N	N	TO	0
BYU	AFA	BYU	1-3-06	5	3	0	0	N	N	Foul	1
BYU	AFA	BYU	1-3-06	6	8	2	0	Y	N	3 make	3
BYU	AFA	BYU	1-3-06	7	5	1	1	N	Y	Foul	1
BYU	AFA	BYU	1-3-06	8	2	0	5	N	N	2 miss	0
BYU	AFA	BYU	1-3-06	9	9	1	2	N	N	2 make	2

Ensuring Data Accuracy

While parameters have been established to ensure that the data collected is reliable and accurate, there are some levels of subjectivity required by the researcher, namely determining when a player is within scoring position, determining when a player is in the post area, and determining when an assist should be credited. To ensure that the data were recorded accurately there will be a categorical audit performed on the three areas in question. The auditor will first be trained on what to look for when dealing with the three subjective areas. This will be accomplished by showing the auditor 10 examples each of what is inacceptable scoring position, post position, and what constitutes an

assist. The auditor will also be shown 10 examples each of what is not in acceptable scoring position or post position, and what would not be constituted as an assist. Lastly, the auditor will be shown 10 examples for each of the three categories that represent a grey area where the auditor would have to use subjectivity to determine what to record.

Following the training session the auditor will go through a practice session where he is randomly given 100 different plays that he will game chart following the same guidelines as the researcher. This practice session is designed to make the auditor comfortable with the process and help him gain additional experience in deciphering between the subjective elements of the study.

After the practice session is completed the auditor and the researcher will be shown 100 randomly selected plays and individually they will chart those plays. At the conclusion of the 100 plays the game charts of the auditor and the researcher will be examined to determine if at least 80% of their responses agree. If there is an 80% agreement or higher among the two parties' responses then the data will be deemed reliable and accurate.

Data Analysis

The data collected through game charting will be statistically analyzed using a Bayesian hierarchical model. This model was selected because in addition to dealing with the parameters chosen for this study it can also deal with basketball parameters that cannot be game charted, namely unequal opponent team strength, home court advantage, and the different defensive strategies employed by the opposition. This is possible through a Bayesian approach because the model determines the posterior distribution by

combining previous knowledge concerning these parameters with the current data. The null hypotheses will then be evaluated using the posterior distributions of the parameters associated with the effects of primary interest, namely touches per play, post touches per play, and DEP. If the 95% posterior intervals associated with these parameters include 0, then the null hypotheses will not be rejected. However, if the 95% posterior intervals associated with these parameters do not include 0, then the null hypotheses will be rejected and it will be concluded that the effects of interest do affect the outcome variables under consideration.

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