THE STATISTICAL IMPACT OF THE LOUISVILLE SLUGGER ‘CATALYST’ BAT ON THE 2005 DIVISION I COLLEGIATE SOFTBALL SEASON

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ABSTRACT

DANA LOUISE SORENSEN: The Statistical Impact of the Louisville Slugger 'Catalyst' bat on the 2005 Div I Collegiate Softball Season
(Under the direction of Barbara Osborne)

This study investigated the relationship between composite bat technology and 13 offensive statistics. In addition to bat technology it analyzed the relationship between ball Coefficient of Restitution and offensive statistics. The study included 28 NCAA Division I Louisville Slugger Sponsored programs from the 2002, 2003, 2004 and 2005 seasons. All teams were using the same Louisville Composite bat in the 2005 season; the 'Catalyst' and all had the same choices of Louisville bats to choose from in 2002, 2003, and 2004. The ball has been changed from a COR of .50 to a .47. The results indicated that there was no effect for the change in COR, but that there was an effect for change in bat technology. Of the seven statistical categories utilized in the one-way ANOVA, five of them returned a significant result and two did not. The results further indicated that the change in bat is significant in producing more home runs, higher slugging percentages, and better batting averages. The descriptive statistics indicated a dramatic increase in mean home runs and mean hits, with a 45% increase in mean homeruns in 2005.

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PREFACE

As a Division I collegiate softball player for five years, I experienced the difference of a composite bat, but only from a biased players perspective. When I played, my team did not have the bat, but my opponents did. I always had the opinion that the other bats were better, and as a pitcher I was pitching against another obstacle. With this thesis I wanted to apply a more scientific approach to measuring the true effect of these new bats, and see if I could justify or disprove my very unscientific hypothesis that I had developed as a player. With the help of my graduate program I have been able to take a small part of the fastpitch softball game into the academic universe. I hope this study will help answer some of the questions regarding the evolution of the equipment used in fastpitch softball.

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CHAPTER I

INTRODUCTION

On March 1, 2003 Easton Bat Company introduced the first composite bat to the game of fastpitch softball (Press Release Easton Bat Company, 2003), two years later Louisville Slugger introduced their composite bat to the fastpitch community (personal communication, Rob Partin, 10/17/05). Bat technology has experienced rapid growth over the last five years, and companies have been able to fine tune their equipment striving to reach higher levels of performance. Softball has been confined to aluminum or graphite bats, until now. The latest bat technology has brought this composite technology to the forefront of the game, and left aluminum bats trailing in the dust (Easton Bat Company Press Release, 2004).

The 2003 collegiate softball season witnessed the first ever use of a composite bat during game competition. During that season only teams swinging Easton bats had access to the new composite Synergy model. Teams swinging any other company's bats were limited to only aluminum bats for that season as well as the 2004 season. As collegiate baseball has had to revisit their bat standard and adjust the parameters to ensure the safety of players, the collegiate softball community has yet to face such a situation. The question of safety in the game is based on the batted ball exit speed, which then determines the reaction time for the defenders in the field. If the ball is flying off the bat at a quicker velocity it could be assumed that the ball would travel a further distance before landing. Also it can be assumed that the quicker the ball is traveling off the bat the faster the ball will travel, even after it hits the ground -- so the faster the ball will be traveling whether in the air or on the ground, the less time the defenders will have to field it. To counteract the effect of increasing bat productivity the NCAA mandated a new ball be used starting in the 2004 season. Balls are tested on two measurements, the compression and the COR, which stands for coefficient of restitution, or more easily understood in terms of how fast a ball will bounce off a wall (ASA Softball Bat and Ball Certification Program, 2004). Compression on the other hand is how much force is needed to squeeze the ball .25 of an inch. The 2003 softball was a .50 COR, meaning that the ball speed bouncing off a wall was cut in half (ASA Softball bat and ball certification program, 2004). The new softball is a .47 COR, so the ball is bouncing off the wall at slightly less than a half speed. According to the Amateur Softball Association (ASA), which governs amateur slow pitch and fast pitch in the U.S, if a ball is thrown at a wall at 60 mph the exit speed of the new COR, .47, will be 27 mph compared to 30 mph of the old .50 COR (ASA Softball Bat and Ball Certification program, 2004).

Most of the Division I programs in the NCAA have sponsors that provide the equipment necessary to compete. The most popular companies are Louisville Slugger (owned by Hillerich & Bradsby), Easton, and Worth (which is owned by Rawlings Baseball). With sponsorship from one of these companies college programs are ensured top of the line equipment for all of their players. As the equipment technology advances the benefits to securing a solid sponsorship deal become increasingly important to the success of any Division I softball program.

Statement of Purpose

The purpose of this study was to address the potential statistical significance of the offensive impact of bat composition, change in ball compression, and a combination of both for a select number of sponsored Louisville Slugger teams. A variety of offensive categories were based on the team statistics of batting average, slugging percentage, runs per game, home runs, triples, doubles, singles, total bases, and on – base percentage. The reason for analyzing the offensive statistics was to examine whether the usage of the composite bat increases the offensive power of those teams that choose to swing a composite bat.

Research Questions

1. Is there a statistical difference in offensive statistics for teams using the Louisville Slugger composite softball technology?
2. Is there a statistical difference in offensive statistics for teams playing with a decreased ball compression?
3. Is there a statistical difference in offensive statistics for teams using the Louisville Slugger composite bat, and playing with the decreased ball compression?

Null Hypothesis

1. There is no significant statistical difference in offensive statistics for teams playing with the decreased ball compression.
2. There is no significant difference in offensive statistics for teams using the Louisville Slugger composite (Catalyst) bat.

3. There is no significant statistical difference in offensive statistics for teams playing with the decreased ball compression and using the Louisville Slugger composite (Catalyst) bat.

Research Hypothesis

1. There will be a significant statistical difference in offensive statistics for teams playing with the .47 compression.
2. There will be a significant statistical difference in offensive statistics for teams using the Louisville Slugger composite (Catalyst) bat.
3. There is a significant statistical difference in offensive statistics for teams playing with the Louisville Slugger composite (Catalyst) bat (2005) and the .47 ball compression (2004).

Significance of Study

A grave concern in the game of collegiate softball is that the technology is advancing the game faster than what is naturally expected. While the most important question in the technology of the bat is safety of the players on the field, that is almost impossible to measure given the short amount of time the composite bat has been in play, and the lack of data on injuries suffered from balls coming off a composite bat. Given this information, the next most pertinent question is how the game is changing as a result of the rapidly advancing technology.

With offensive statistic improving each year, the question remains how much does the technology of the equipment change the game? It is more than understood that if major league ball players were to be swinging aluminum bats as opposed to their wood bats the balls would be leaving the ball park at an alarming rate, and the batted ball exit speed would be so fast that it would leave virtually no reaction time for the fielders. In addition to that college baseball has strictly limited the aluminum bats allowed, so much so that players are only allowed to swing bats that have no more than a difference of three between height and weight. (I.e. a bat length of 35 inches may weigh no less than 32 ounces.) With this rule they are able to slow down the bat swing speed of the athletes and thus slow down the speed of the ball coming off the bat.

In the game of baseball it is accepted that technology can affect the game, and because of that, rules have been enacted to counter such an effect. Softball on the other hand has yet to address such a concern. No one has yet to ask the question or raise the issue of whether we should be following the footsteps of our counterpart and work to control the technological advances with respect to the equipment used. This study is intended to quantify the offensive changes of this technological advancement and assess how they are affecting the game.

The NCAA prides itself on ensuring that they are in existence to create a fair playing field, but with the rapidly changing technology is that really the case? Are teams that are playing without the supply of composite bats truly at a disadvantage? The overall goal is to provide more information to create a more educated bat standard for the collegiate softball game that allows for concern for student-athlete safety as well as a fair playing field for all teams and players.

Definition of Terms

Batted Ball Percentage

Batted ball percentage is the total number of hits divided by the total times the ball was put in play (divide total hits by the total number of at – bats minus total strikeouts, walks, hit by pitches and sacrifice bunts).

Batted Ball Home Run Percentage

Batted ball home run percentage is the total number of home runs divided by the total number of times the ball was put in play (divide total homeruns by the total number of at – bats minus total strikeouts. Walks, hit by pitches, and sacrifice bunts are not counted as at bats).

Batted Ball Singles Percentage

Batted Ball Singles percentage is the total number of singles divided by the total times the ball was put in play (divide total singles by the total number of at-bats minus total strikeouts. Walks, hit by pitches, and sacrifice bunts are not counted as base hits.)

Batted Ball Doubles Percentage

Batted ball doubles percentage is the total number of doubles divided by the total number of times the ball was put in play (divide total doubles by the take total number of at – bats minus total strikeouts. Walks, hit by pitches, and sacrifice bunts are not counted as at bats).

Batted Ball Triples Percentage

Batted ball triples percentage is the total number of triples divided by the total times the ball was put in play (divide total triples by the total number of at-bats minus total strikeouts. Walks, hit by pitches, and sacrifice bunts are not counted as base hits).

Batted Ball Slugging Percentage

Batted ball slugging percentage is the total number of bases divided by the total times the ball was put in play (divide total bases by the total number of at – bats minus total strikeouts. Walks, hit by pitches, and sacrifice bunts are not counted as base hits.). This will tell you on average how many bases were touched per ball put in play.

Composite
Composite material is a compilation of epoxy, resin, and fibers, as opposed to metals.

Catalyst
Catalyst is the name of Louisville Slugger's composite bat.

Synergy
Synergy is the name of Easton's composite bat

Batting Average
Batting average is the number of total hits divided by the number of total at – bats.

Slugging Percentage
Slugging percentage is the number of total bases divided by the number of hits

Total Bases
Total bases are the number of base touched by the offense, during the season.

Batted Ball Exit Speed
Batted ball exit speed is the speed of the ball coming off the bat after impact.

Louisville Slugger
Louisville Slugger is the baseball and softball company owned and operated by Hillerich and Bradsby.

Assumptions

It has been assumed that the bats being swung by the sponsored Louisville Slugger teams are almost entirely the Catalyst, as opposed to aluminum or graphite Louisville Slugger bats. It will also be assumed that each team is facing the similar level of competition on average throughout the season, as was faced during their previous four seasons. It has been assumed that the number of games played on a variety of field sizes is about the same as the previous four seasons. It has also been assumed that aluminum (non – composite) bats have not had a drastic change in the last four years.

Limitations

Because the data was measured in real life situations there were variables out of our control. The number of players changes from year to year and with that the quality of players' changes from year to year as players develop from their freshman year on. The number of games changes from year to year, especially depending on the amount of post season games played.

Delimitations

This study is restricted to the population of Louisville Slugger sponsored teams in Division I collegiate softball. The study cannot be generalized out to all teams that swing composite bats of various companies because there is no knowledge on how these bats compare to each other. It also cannot be generalized to any other level of play than Division I softball, i.e. no Division II, or III, or high school or club ball can be included because there is no data taken on the offensive statistics of their divisions. No data can be collected on these other NCAA divisions or high school because there isn't a single bat sponsorship per team. The choice of bat is a personal decision, and usually must be paid for by that individual. The result is a variety of companies and types of bats used on any one team.

CHAPTER II

REVIEW OF LITERATURE

Composite bat technology is so new and fresh to the fast – pitch and slow pitch softball scene that there has been little time for research to develop. Most of the research related to bat technology has been done on baseball's aluminum and wood bats. There are big enough offensive differences, and potential safety concerns, regarding aluminum bats that Major League Baseball (MLB) has prohibited them from use in their league. NCAA baseball, on the other hand, does allow the use of aluminum bats in their game, and they have experienced an increase in offensive statistics, as compared to MLB. While there isn't any valid study to support this, a simple look at the range of batting averages and home run production indicates a difference between the two levels. In MLB a .400 hitter (4 hits out of every 10 at bats) is extremely rare: the last player to hit over .400 for the season was Ted Williams in 1941, with a batting average of .406 (http://mlb.mlb.com/NASApp/mlb/stats/). In the NCAA, handfuls of baseball players hit over .400, including the highest all time batting average at .551 (http://www.NCAA.org/library/records/baseball). As for homeruns, MLB's single season home run mark was set by Barry Bonds in 2001 with 72 (http://mlb.mlb.com/NASApp/mlb/stats/) in 153 games played. The NCAA single season mark is 48 in 75 games played (http://www.NCAA.org/library/records/baseball).

Since there are no fastpitch softball players swinging wooden bats, the only bat comparison there is for softball is among aluminum bats. With aluminum bats, the topic to be discussed is not just performance but player safety as well. The big question facing player safety is the reaction time allowed from batted balls off composite bats. There is one pertinent study from *The Sport Journal*, McDowell, Ciocco, & Morreale (2005), A Composite Softball Bat Revolution: Why the Pitcher has Little Time to React to a Batted-Ball assesses this exact issue of batted ball speed and fielder reaction times with respect to composite bats. Another article also pulled from *The Sport Journal,* Hardball – hardbat: A call for change from aluminum to wooden baseball bats in the NCAA, addresses both safety and increased offensive numbers in NCAA baseball (Kelly & Pederson, 2000).

The impact of equipment changes in other sports will also be examined. Golf has seen equipment advances in the design of clubs, specifically woods and drivers. In golf, safety is not the primary issue, but the technology has created a problem very similar to that of baseball and softball. A concern has been addressed that average players are now able to strike the ball as far as or further than the professional golfers years ago. Golf courses are now designing and redesigning courses to be more difficult, to offset the increase in lower scores (Walker, 1999). The trend in golf club technology has led to the boom of the industry: as of 1999 it was at $2 million.

Not all equipment changes have come in ball striking sports. In 1984, the size of women's basketball was decreased in hopes of increasing offense in the women's game (Hamryka, 1986). The importance of this literature review is the model of statistical testing that is used to measure the pre- and post- effect of a change in equipment within a sport.

Composite Bat Testing on Batted Ball Velocities and Reaction Times

McDowell, Ciocco, and Morreale (2005) studied the differences in Batted Ball Velocity with both wooden and composite softball bats. The composite bats tested were the Easton Synergy+ and the Miken Freak. Essentially, Batted Ball Velocity is the measurement of how fast a ball is coming off a bat. For their study, McDowell, Ciocco, and Morreale utilized three slow-pitch softball players swinging two different wooden bats, two different composite bats, and three different ball compressions. Ball compression is the amount of force required to compress the ball .25in. Each player hit pitches from a pitching machine set at 16 – 25 mph, and a radar gun was used to measure the batted ball speed. The standard deviation for each Batted Ball Velocity measurement was 2.4 mph, as set by the 95% confidence interval. Each player recorded five measurements out of seven swings for each bat at each level of ball compression. The results of the study were listed in ranges of batted ball speeds, which included all three compression rate softballs. The wooden bats measured a range of 78.3 mph on the low end and 85.0 mph on the high end. The composite bats measured 89.2 mph on the low end and 102.1 on the high end

McDowell, Ciocco, and Morreale successfully contribute to the argument that composite bats create an increase in Batted Ball Velocity. However, there are some limitations to their study in reference to this one. The first limitation is the comparison of wooden bats to composite bats. This is almost irrelevant data, as virtually no one uses wooden softball bats. Secondly, they utilized slow-pitch players in their study. These players were 71inches and 220 pounds on average, a size attributed most commonly with males. It is assumed that the swing velocities of softball players are related to size and strength of the person swinging. Third, this study uses slow-pitch speeds from the pitching machine. Fastpitch softball has much faster pitch speeds, ranging anywhere from 55 – 70 mph. Regardless of the limitations of the study with respect to fastpitch, McDowell, Ciocco, and Morreale still prove that composite bats generate increased Batted Ball Velocities.

Baseball Wooden Bats vs. Aluminum

Kelly and Pederson (2000), Hardball – hardbat: A call for change from aluminum to wooden baseball bats in the NCAA, argue for a change to be made in NCAA baseball bats from aluminum to wooden. They claim that aluminum bats are creating unnecessary dangers in college baseball due to the increase in exit velocity in aluminum bats versus exit velocities in wooden bats, (Kelly & Pederson, 2000 ¶ 2). In their article they reference the change in offensive statistics: batting average is up from .296 to .301 in a 15 year period, home runs from .80 per game to .91 per game, and runs per game to 6.81 as compared to 6.49. Their argument is that the usage of aluminum bats distorts player development and hinders college baseball players from being as successful in professional ball where they are required to use only wooden bats. They use one particular college baseball player as an example in that his collegiate stats were much higher than his first year minor league stats.

Kelly and Pederson's article lacks any statistical evidence to support their offensive statistics. With the change in numbers being measured over such a long period of time it is impossible to say that the numbers are not a product of the growth of the sport as much as they are due to the nature of the bat. While they cite the differences in professional statistics and collegiate statistics as proof of their argument, they do not limit this assumption to the other potential factors such as increased level of pitching in professional ball.

Equipment Changes in Basketball

The Bonnie Hamyrka's 1986 UNC master's thesis study, Comparison of the effect of ball size on the performances of Atlantic Coast Conference women's basketball teams, researched the impact of the size of the women's basketball and found no statistically significant difference in statistics due to the size of and weight of the ball in women's college basketball teams in the Atlantic Coast Conference (ACC) from 1982 – 1986. The study measured shooting percentage, per game average of total points, rebounds, steals, assists, turnovers, personal fouls, and a composite of these statistics, which was used for overall performance, known as PERF. Prior to the study, basketball overall performance was measured through attitude scales, season statistics, and controlled skills test situations.

The purpose of the study was to assess the impact of a smaller ball, measuring 28.5 in circumference and 18 oz in weight, on the overall game of women's college basketball. The previous size of the ball was 1.5 inches bigger and two ounces heavier. The smaller and lighter ball was introduced in the 1984 – 85 season. There were eight hypotheses tested, stating there will be no significant difference in overall performance, shooting percentage, average total points, rebounds, steals, assists, turnovers, personal fouls. The hypotheses were tested using all eight teams from the ACC through the 1982 -1986 seasons. Overall performance was measured on the PERF formula which is shooting percentage minus personal fouls minus turnovers. ACC per game averages were measured for each skill (i.e. rebounding, turnovers, assists, etc.), by combining all statistics for each team and dividing it by number of teams. The data failed to reject any of the eight hypotheses, reaching no significant differences with p values for each hypothesis at less than .05. The study includes season by season breakdowns of each category and a comparison between each season.

This study is important because it provides a similar statistical analysis of how to measure both pre- and post- effects of actual game statistics. The data collected in this basketball study is similar to the data collected in this composite bat study. Both studies have compiled data from actual seasons played which gives both increased value and similar limitations.

Summary of Relevant Research

The research on composite bat technology and fastpitch softball is extremely limited. However the studies in this chapter have given rise to the importance of continuing research. *A Composite Softball Bat Revolution: Why the Pitcher has Little Time to React to a Batted-Ball,* proves the point that composite bat increases the batted ball velocity as faster than that of wooden. Further research is now needed to compare the composite to the aluminum bat. Hardball – hardbat: A call for change from aluminum to wooden baseball bats in the NCAA proves that there is a statistical difference in the offensive production of aluminum bats over time. As simple technologies in aluminum bats advance there is a change in offensive production. So if there is a statistical difference in aluminum bats through the years, what then is the difference in aluminum and composite bats? Bonnie Hamyrka's study on the ball changes in ACC women's basketball revealed no significant change in statistics. That study provided an example of how a statistical analysis might be run when looking at offensive statistics over a length of time and with equipment changes. The previous studies have provided a solid starting ground from which to build, but have not adequately covered the topic of softball bat performance or composite bat performance. It seems accurate to say that composite bats have a potential to increase the Batted Ball Velocity -- what needs to be explored next is if this increase in Batted Ball Velocity translates into an increase in the offensive statistics within the game.

CHAPTER III

METHODOLOGY

The purpose of this study was to address the potential statistical significance of the offensive impact of bat composition, change in ball compression, and a combination of both for a select number of sponsored Louisville Slugger teams. A variety of offensive categories were based on the team statistics of batting average, slugging percentage, runs per game, home runs, triples, doubles, singles, total bases, and on – base percentage. The reason for analyzing the offensive statistics was to examine whether the usage of the composite bat increases the offensive power of those teams that choose to swing a composite bat.

Unit of Analysis

The sample for this study included Division I softball programs sponsored by Louisville Slugger totaling 28 teams from 15 different conferences (there are 30 total Division I conferences). The list of sponsored teams was given to me by Rob Partin, collegiate sales representative for Louisville Slugger, and it included a total of 34 teams. From this list, teams were eliminated if they were not Division I (California College of PA, Central Arizona College, Oklahoma City Colley, Palomar Community College), and if they were sponsored by a different bat company the previous seasons (University of Washington, and Wichita State University). Only sponsored teams were used in the survey, even though there are other Division I teams that use the Louisville Slugger 'Catalyst' by there own choice. The reason being is that the variability in bat choice can not be controlled unless they are sponsored. Team statistics were gathered from the 2002, 2003, 2004, and 2005 seasons. The 2002 and 2003 seasons were non composite and high ball compression (.50), the 2004 season was non composite bat and low ball compression (.47), and the 2005 season was the composite bat and low compression ball.

Table 1
Season and Corresponding Ball Type and Bat Type

YEAR	**BALL COR**	**BAT TYPE**
2002	.50	Non – composite
2003	.50	Non – composite
2004	.47	Non – composite
2005	.47	Composite

The 28 Louisville Slugger sponsored teams included in this study are: Arizona State University, Auburn University, University of Central Florida, Central Michigan University, DePaul University, University of Florida, Hofstra University, University of Illinois-Chicago, University of Iowa, Long Beach State University, University of Louisiana Lafayette, University of Louisville, University of Michigan, University of Nevada Las Vegas, University of North Carolina, Northern Illinois University, Northwestern University, Ohio State University, University of the Pacific, Penn State University, University of South Carolina, University of South Florida, Stanford University, Stetson University, Syracuse University, Texas A&M University, Virginia Tech University, and the University of Wisconsin.

Instrumentation

The overall offensive performance of the 28 teams was based on 14dependent variables: batting average, slugging percentage, total hits, total home runs, total singles, total doubles, total triples, total runs, batted ball hits percentage, batted ball home run percentage, batted ball singles percentage, batted ball doubles percentage, batted ball triples percentage, and batted ball slugging percentage.

Procedures

Data was collected using an archival methodology. Data was collected using each team's athletics website, which posts season statistics in all the variables selected, listed following each perspective season, and categorized by team and individual. In some situations it was necessary to contact the sports information department for programs that do not post statistics from past seasons.

Statistical Analysis

The statistical test chosen for this study was a one way between subjects ANOVA with a Tukey Post Hoc test for each of the pair wise comparisons. The one-way ANOVA was only run on the categories that involved percentages: slugging %, batting average, and the six batted ball percentages, hits, home runs, singles, doubles, triples and slugging. For the other statistical categories -- total hits, home runs, doubles, and triples -- a simple descriptive statistics analysis was run. Since there are varying numbers of games in each season for each of the 112 teams (4 years x 28 schools) there isn't a specific statistical method to run to compare the differences.

CHAPTER IV

RESULTS

Introduction

The purpose of this study was to determine the statistical impact of changing bat technology and ball compression on the seasons of selected Louisville Slugger sponsored Div I softball programs. There were a total of 34 programs sponsored by Louisville Slugger, and six were eliminated because they either were not a Division I program, or because they haven't been using Louisville Slugger bats exclusively during the period of the study, 2002-2005. That leaves a total of 28 programs for the study yielding 112 total teams. There were 14 total statistical categories, eight were being analyzed with the one-way between subjects ANOVA (batting average, slugging percentage, batted ball hits percentage, batted ball singles percentage, batted ball doubles percentage, batted ball triples percentage, batted ball home run percentage, batted ball slugging percentage) and the other six with simple descriptive statistics (total hits, total runs, total singles, total doubles, total triples, total homeruns).

Descriptive Statistics

For the total Runs variable the means recorded for each year ranged from 214.36 to 275.11, with 2003 having the lowest and 2005 recording the highest. For the complete breakdown on the descriptive statistics please refer to the Table 2.

For the total Singles variable the means recorded for each year ranges from 275.79 to 325, with 2003 having the lowest and 2002 recording the highest.

For the total Hits variable the means ranged from 384 from 451, with 2003 being the lowest and 2005 at the highest.

For the total Doubles variable the means ranged from 66.53 to 76.85, again with 2003 recorded the lowest mean and 2005 scoring the highest.

For the total Triples variable the means ranged from 7.93 to 10.18. This time 2004 scored the lowest mean and 2005 recorded the highest.

For the total Homeruns variable the means ranged from 32.46 on the low end and 48.18 on the high end. Just like in the triples category, 2004 came in with the low mean and 2005 held the high mean.

In all of the descriptive statistics variables, with the exception of total Singles, 2005 scored the highest means, and in all but the total Hits and total Singles categories 2005 had the highest maximum. While the statistical impact test cannot be run on these categories it is interesting to note that 2005 continually recorded higher numbers than that of any other year in almost all of the six categories.

Table 2
Descriptive Statistics Results

	YEAR	N	Minimum	Maximum	Mean	*Std. Deviation*
RUNS	**2002**	28	146	368	251.18	*57.65*
	2003	28	114	334	214.36	*64.17*
	2004	28	127	405	237.07	*60.48*
	2005	28	151	419	275.1	*62.23*
HITS	**2002**	28	311	604	439	*69.76*
	2003	28	239	565	384.43	*74.09*
	2004	28	280	616	426.04	*71.33*
	2005	28	300	615	451.5	*77*
SINGLES	**2002**	28	246	444	325	*49.38*
	2003	28	183	439	275.79	*54.86*
	2004	28	202	478	217.64	*55.99*
	2005	28	*213*	*425*	*316.29*	*53.44*
DOUBLES	**2002**	28	46	106	72.39	*17.27*
	2003	28	27	102	66.54	*16.35*
	2004	28	43	96	69.96	*13.47*
	2005	28	42	107	76.86	*13.52*
TRIPLES	**2002**	28	3	19	9.21	*4.38*
	2003	28	2	22	8.14	*4.90*
	2004	28	3	19	7.93	*3.92*
	2005	28	1	31	10.18	*6.33*
HOMERUNS	**2002**	28	8	76	32.75	*15.53*
	2003	28	10	79	33.96	*15.04*
	2004	28	9	88	32.46	*14.63*
	2005	28	19	103	48.18	*17.86*

One Way Between Subjects ANOVA

To answer the three hypotheses proposed the one-way between subjects ANOVA was used on the eight percentage dependent variables. Within those three hypotheses it was hypothesized that the ball COR, composite bat, and the combination of the ball COR and composite bat would have no effect on the overall offensive statistics being analyzed.

For the Batting Average variable the omnibus test indicated a significant effect, with a p-value of .010. With the Post Hoc Tukey test a significant impact was recorded for year comparisons in the 2003 to 2005 season, yielding a p-value of .029. There were no other pairwise comparisons that had a significant effect.

For the Slugging Percentage variable the omnibus test indicated a significant effect, recording a p-value of .011. Using the Tukey test as our Post Hoc analysis the pairwise comparisons revealed a significant effect for 2003 compared to 2005, with a p-value of .006

Both of these tests are important, not as much for the effect it has on significance, but more for the importance of the batted ball variables. Since there is a significant effect for Batting Average and Slugging Percentage, there is a good probability that there will be an effect for the batted ball tests, since those eliminate the times when the ball is not put in play (i.e. strikeout). By eliminating some of the skill in the hitting equation (both on the hitting and pitching end) it will help ensure that the only thing being examined is the bat and/or ball.

For the Batted Ball Hits Percentage the omnibus test indicated a significant effect with a p-value of .000. With the Tukey Post Hoc pairwise comparisons there were significant effects measured for the 2003 v. 2005 seasons and the 2004 v. 2005 seasons.

For the Batted Ball Singles Percentage the omnibus test indicates that there is a significant effect, recording a p-value of .004. With the Tukey Post Hoc pairwise comparisons the results indicate that there is only one significant finding, the 2002 to 2003 seasons with a p-value of .003. There are no pairwise comparisons for any of the 2005 comparisons. In all of the variables analyzed that resulted in the significant difference (Batting Average, Batted Ball Hits Percentage, Batted Ball Singles Percentage, Batted Ball Home Run Percentage, Slugging Percentage, and Batted Ball Slugging Percentage) there was a significant difference in the 2003 season in comparison to one of the other 3 seasons.

For the Batted Ball Doubles Percentage the omnibus test indicated no significant effect, recoding a p-value of .187. No pairwise comparisons were needed.

For the Batted Ball Triples Percentage the omnibus test indicated no significant effect, recording a p-value of .297. No pairwise comparisons were needed.

For the Batted Ball Homerun Percentage the omnibus test indicated a significant effect, recording a p-value of .001. With the Tukey Post Hoc test the pairwise comparisons with a significant effect were 2002 to 2005, 2003 to 2005, and 2004 to 2005. None of pairwise comparisons outside the 2005 season had any significant effect.

For the Batted Ball Slugging Percentage the omnibus test indicated a significant effect, recording a p-value of .000. With the Tukey Post Hoc test the pairwise comparisons with a significant effect were again 2002 to 2005, 2003 to 2005, and 2004 to 2005.

Table 3
Omnibus Test P-Values for all Dependent Variables

VARIABLE	**P - Value**
Batting Average	.010*
Slugging %	.011*
Batted Ball Hits %	.000*
Batted Ball Singles %	.004*
Batted Ball Doubles %	.187
Batted Ball Triples %	.297
Batted Ball Homerun %	.001*
Batted Ball Slugging %	.000*

*indicates significant p – value (alpha < .05)

The first hypothesis was the change in ball COR (coefficient of restitution) from 0.50 to 0.47. The 2002 and 2003 seasons used the .50 ball COR and the 2004 and 2005 season used the .47. Since the 2005 season used the composite bat as well as the new ball COR, it cannot be assumed that the change in statistics would be a sole result of the ball. The 2004 season is used as the basis for whether the ball COR had a significant effect on the eight variables. While all but two of the eight variables yielded a significant result in our initial omnibus test, there were no significant pairwise comparisons between 2002 and 2004, and 2003 and 2004. Therefore we fail to reject the hypothesis that there will be no significant effect in the change of the ball COR from .50 to .47.

Table 4
Pairwise Comparisons: 2002 v 2004, 2003 v 2004

VARIABLE	2002 v 2004	2003 v 2004
Batting Average	.197	.995
Slugging %	.986	.693
Batted Ball Hits %	.592	.955
Batted Ball Singles %	.740	.051
Batted Ball Doubles %	.855	.962
Batted Ball Triples %	.959	.249
Batted Ball Homerun %	.997	.652
Batted Ball Slugging %	.822	.854

* indicates a significant p – value (alpha < .05)

The second hypothesis focused on the composite bat, stating that there would be no effect of the Louisville Slugger Catalyst bat on the offensive statistics of the 2005 softball season. Since the bat was not in use during the 2002, 2003, or 2004 seasons, the season of interest is 2005. Since 2004 utilized the same ball COR, 0.50, narrowing our scope of analysis down to just the 2004 and 2005 seasons allows it to be solely focused on the effect of the bat, not the effect of the bat and ball. From the data analysis the Batted Ball Hits

Percentage, the Batted Ball Home Run Percentage, and the Batted Ball Slugging Percentage all resulted in a significant effect for the 2004 season compared to 2005. For Batted Ball Hits percentage the p-value was .003, for Batted Ball Home Run percentage the p-value was .001, and for Batted Ball Slugging Percentage the p-value was .000. The null hypothesis is ultimately rejected for the variables stated above, but fail to reject for any of the other variables used in the study: Batting Average, Slugging Percentage, Batted Ball doubles percentage, and Batted Ball triples percentage. For complete ANOVA results, both for the omnibus test and for the pairwise comparisons please refer to Appendix A.

Table 5
Pairwise Comparisons: 2004 v 2005

VARIABLE	**2004 v 2005**
Batting Average	.054
Slugging %	.115
Batted Ball Hits %	.003*
Batted Ball Singles %	1.000
Batted Ball Doubles %	.156
Batted Ball Triples %	.878
Batted Ball Homerun %	.001*
Batted Ball Slugging %	.000*

*indicates significant p – value (alpha level < .05)

The third hypothesis addressed the combination of both the change in bat technology and the change in ball COR. To test this hypothesis the pairwise comparisons necessary are the 2002 and 2003 seasons compared to the 2005 season. 2002 and 2003 represent no change in bat technology and no change in ball COR (ball COR at 0.50), while the 2005 season represents both change in bat technology and change in ball COR (ball COR at 0.47). The 2004 season was overlooked for this analysis because it only reflects a change in bat technology there was no change in ball COR. Significant results were recorded for the Batted Ball hits percentage for the 2003 to 2005 comparison (p-value at .000), for Slugging Percentage for the 2003 to 2005 comparisons (p-value at .006), for Batted Ball Hits Percentage for the 2003 to 2005 season (p-value at .000), for the Batted Ball Home Run Percentage for both the 2002 and 2003 seasons (p-values at .003 and .043 respectively), and finally for the Batted Ball Slugging Percentage for both the 2002 and 2003 seasons (p-value of .003 for both seasonal comparisons). From this analysis the null hypotheses is rejected for the Batting Average, Slugging Percentage, Batted Ball Hits Percentage, Batted Ball Home Run Percentage, and Batted Ball Slugging Percentage; and fail to reject the hypothesis for our last two variables: Batted Ball Doubles Percentage and Batted Ball Triples Percentage.

Table 6
Pairwise Comparisons: 2002 v 2005, 2003 v 2005

VARIABLE	**2002 v 2005**	**2003 v 2005**
Batting Average	.937	.029
Slugging %	.228	.006*
Batted Ball Hits %	.101	.000*
Batted Ball Singles %	.709	.058
Batted Ball Doubles %	.557	.370
Batted Ball Triples %	.995	.678
Batted Ball Homerun %	.003*	.043*
Batted Ball Slugging %	.003*	.003*

* indicates a significant p – value (alpha <.05)

CHAPTER V

DISCUSSION

Summary

From the results of the one – way ANOVA analysis on the eight dependent variables and descriptive statistics for the other six dependent variables there is plenty of information on how the composite bat and ball COR affects the current game of fastpitch softball at the Division I collegiate level. The purpose of the study was to find out whether or not there is an affect on the game with both a different ball COR and new bat technology. The findings indicate that there is no statistical significance in changing the ball compression from 0.50 to 0.47, but there is a statistical significance in changing the bat from aluminum to composite, and there is significance in changing the ball and the bat. With the change in bat the variables that were significant were those indicating offensive power, i.e. home runs, and slugging percentage. With respect to the game, these results indicate that the change in bat has effected offensive statistics by primarily increasing the number of times a home run is hit, thus increasing the total number of bases that are covered, which increases the Slugging Percentage.

Since the data resulted in a significant effect for both the Batted Ball Hits Percentage and the Batted Ball Home Run Percentage it is deduced that there was a significant effect in the number of base hits. Since there is no significant effect for either Batted Ball Doubles Percentage, or Batted Ball Triples Percentage it can be rationed that the change in Batted Ball Hits Percentage from 2002, 2003, and 2004 to 2005 is either a result of an increase in singles or an increase in home run. With no significant effect measure for any of the 2005 pairwise comparisons with the Batted Ball Single Percentage, it strongly suggests that the significance measure in the Batted Ball Hits Percentage is due to the increase in number of home runs, as indicated by the significant effect of the Batted Ball Home Run Percentage. Also the significant effect of the Batted Ball Slugging Percentage is likely due to the significant change in number of Home Runs.

Since 2002 and 2003 had the same bat and ball, the only logical reason that can be inferred from these results is that there was another outside factor contributing to the decrease in offensive numbers for 2003. This could be either stronger pitching that year, not as efficient hitters, or a combination of both.

Even without using the one-way between subjects ANOVA, trends in the five total variable categories (home runs, triples, doubles, singles, and total hits) can be seen. Looking at Table there is almost a 50% increase in the number of home runs in 2005 as compared to all other years, while there is little change in the number of singles recorded.

Table 7
Mean Values of Hits, Homeruns, Triples, Doubles and Singles by Season

Year	**Mean of Total Hits**	**Mean of Total Home Runs**	**Mean of Total Triples**	**Mean of Total Doubles**	**Mean of Total Singles**
2002	439	32.75	9.2	72.39	325
2003	384	33.96	8.14	66.53	275.79
2004	426	32.46	7.93	69.6	317.64
2005	451	48.15	10.18	76.86	316.29

Figure 1
Mean Values for Descriptive Statistics by Season

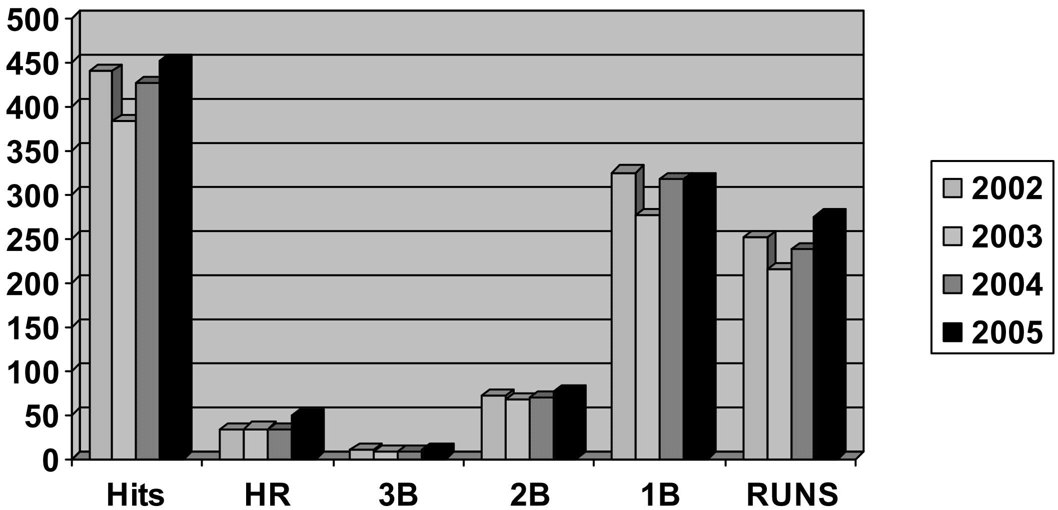
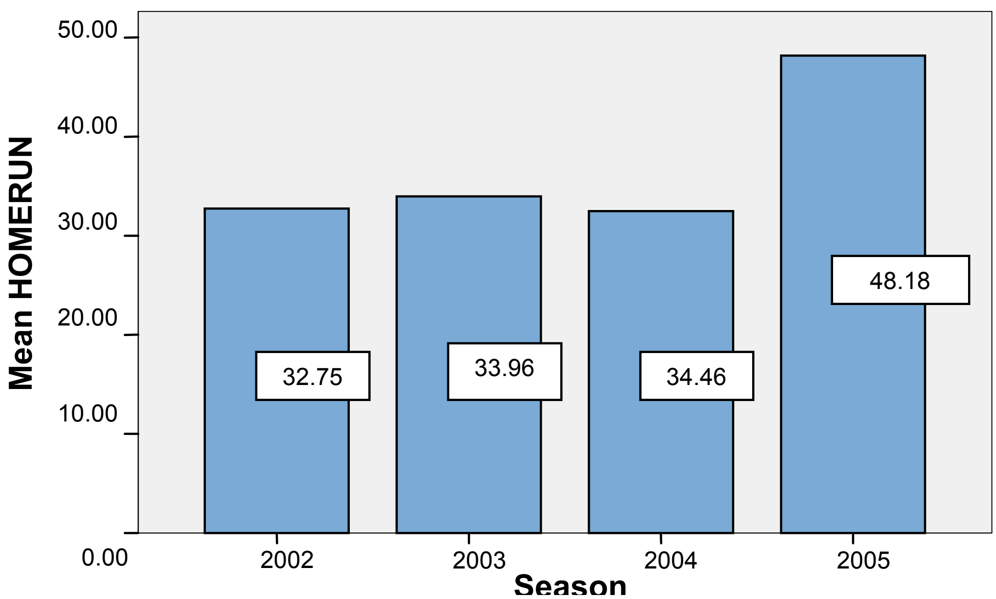


Figure 2
Mean HOMERUNS by Season



After recording all the data and running the one-way ANOVA it is not surprising to see no significant affects for both the Batted Ball Doubles and Batted Ball Triples categories. Both of those statistics have a very small sample size, simply because of the difficulty there is in hitting either a double or triple in the game of softball. With softball, the fences are a good 150-200 feet closer than in baseball. This results in outfielders playing closer to one another and decreasing the amount of field they have to cover. Traditionally doubles and triples are hit in the gaps between the fielders resulting a long way to run for the outfielder in chasing the ball, which gives the base runner more time to run around the bases. Typically triples are hit in these gaps by the faster hitters on the team. Doubles are easier to hit than triples because it is 60 feet less the player has to run. The number of triples and doubles recorded from the 28 teams each year is much smaller than the number of total hits, the number of singles, and the number of total bases covered. From a statistical point of view when running a smaller sample, the result is going to be a smaller effect size. To most accurately measure whether there are significant effects there either needs to be more teams involved in the study, or more games played by those teams currently in the study, which would render more at bats and thus more chances for a double or triple to occur.

The same point can be made for home runs, which occur less often than doubles for most teams, and much more often than triples, again for most teams. Since the sample size for home runs is still very small in comparison to hits, singles, and total bases categories the effect size is still small. What is remarkable is that given the small effect size there is still a significant effect. So increasing the sample size could theoretically increase the gap between the home run totals in 2002, 2003, and 2004 compared to 2005.

After looking at all the significant results both in the omnibus test and the pairwise comparisons there are several that would fall under an alpha level .01. Since the alpha level .05 is applied, the only point to make is that some of the categories have a much lower chance of error than what a .05 indicates. All of the Batted Ball variables that indicated a significant effect in the omnibus test were recorded below a .01, as well as the pairwise comparisons for the Batted Ball Hits, Batted Ball Home Run with the exception of the 2003-2005 comparison, and all of the Batted Ball Slugging Percentage pairwise comparisons. This means that in all of these cases the percentage of times the significant effect could be due to chance and not the composite bat, is less than 1%.

After analyzing all of the data and its results it is safe to say that the game of fastpitch softball at the Division I college level has seen an increase in home runs simply because of the type of bat being used. Why does the bat significantly alter the ability to hit a ball out of the park? From a bat maker's perspective, the goal is to make a bat that increases the batted ball exit velocity. In simpler terms, manufacturers wanted to increase the speed at which the ball comes off the bat at contact. The faster the ball travels the quicker it will get over the fence, and the harder it is for the fielder to run underneath and catch it. Another crucial part of hitting a home run is the angle at which the ball is hit. In other words the trajectory of the ball makes a big difference in what the result of the contact will be. If the ball trajectory is on a downward, or even a horizontal angle then the ball exit velocity won't affect the outcome of the at bat. No matter how fast the ball comes off the bat, if it is not hit in an upward trajectory it will not carry out of the ballpark. The ball must be hit in the air to travel above the fielders reach and over the fence. This is another reason that there were no significant changes in the percentages of doubles and triples hit. It can be estimated that fly balls hit off a non composite bat are now traveling out of the ball park since they are hit at the right trajectory with greater speed so the outfielder doesn't have the time or space to get underneath the ball before it lands. Additionally, with doubles and triples the defense of the team on the field plays a much bigger factor than in homeruns. A good defense, with good outfield speed, and solid throwing arms can get to a ball in the gap faster and get the ball back in to the infielders much quicker, thus preventing doubles and triples. On the other hand, a poor defense with slow outfielders and weak throwing arms will take longer to get to the ball and not have strong quick throws to the infielders, thus resulting in more time for the batter to run the bases resulting in a double instead of a single, or a triple instead of a double. With homeruns, the only defense that can affect it is if the outfielder can get to the fence, reach over, and catch the ball after it is has crossed the fence. This happens more often in baseball simply because the ball is in flight longer, given the deeper outfields. The longer the ball is in flight the more time they have to run to the ball and catch it. With softball the outfield fences are much closer (190 – 220 ft) which does not give the outfielder much time to run underneath the ball and with how fast the ball travels it often gets beyond the outfielders reach very quickly. Because the homerun statistic eliminates the defensive variable, the impact of only the composite bat is even more pronounced.

Another interesting finding from the data analysis is that the change in ball compression has made no statistical impact on the game. As stated in Chapter IV we failed to reject the hypothesis which stated that there would be no significant effect for the change in ball compression. Ball compression was changed after the first year of the composite bat technology (2004).

Recommendation for Further Study

The real concern in the college game with the new bat technology is the potential for increase in injuries among defensive players. From a logical standpoint it is clear that the faster the ball comes off the bat the less time the fielder has to field it. If the ball is hit in an upward trajectory there is an increase in probability that the ball will go over the fence, but what about when the ball is hit on a line or on the ground with the same increase in batted ball exit speed? Fastpitch softball infielders play a lot closer to the hitter than baseball or slow-pitch softball infielders. Considering that the bases for softball are 60 feet as opposed to the 90 feet of baseball, this brings the fielders at least 30 feet closer to the batter. In addition to that, first basemen and third basemen (known as corner players in fastpitch softball) have to get even closer to the batter to prevent the possibility of the batter putting a bunt down and getting on base. In fastpitch softball the short game (bunting and slapping the ball) are very important and very much a part of a hitter's arsenal, so to combat this defense must play about 5 -10 feet in front of the third and first base bags. This puts the fielders at about 55 – 50 feet from home plate. As distance decreases, the time to field the ball also decreases, and thus the reaction time of the fielder is compromised. This is also true for pitchers who are much closer to home plate than baseball pitchers. Softball pitchers start at 43 feet and finish about 34 feet (after they have stepped out and pitched) – in comparison, baseball pitchers start at 60 feet 6 inches and finish about 52 feet from the plate. As with the fielders, if the ball is leaving the bat of the batter at a faster speed, then the pitcher will have less time to react to the ball that is hit back at them. In baseball there have been some frightening instances of a pitcher getting hit by a line drive resulting in serious injuries. With the change in bat technology this could be an increased risk for softball pitchers and infielders.

For further study an injury report analysis would need to be run on the number of players that have been hit by line drives causing significant injuries from a 5 – 10 year span. For the most accurate data this would need to include practice, since players face their own team during practice which is just as dangerous as a game. The other way to study this potential hypothesis is to measure the lowest possible time for a softball player to react to a ball hit at them and then compares that with time it takes a player to react to a ball hit off both composite and non composite bats. There is a maximum exit velocity, by rule, so all reaction times can be based on the maximum exit velocity.

Moving beyond the potential injuries study, there is another result to the significant effect of change in bat technology. Currently in softball, as in any sport, performances are based on the average capabilities of softball players in the past. In other words, whether a player played well is based on what is thought to be a solid game performance. As in Major League Baseball it is known that .400 batting average is very difficult to attain, so anything in the .300 - .400 is a solid offensive season for a hitter. As with homeruns, until recently, the 50 plus homeruns was thought to be a tremendous offensive season. However with the numbers that have been put up recently by Barry Bonds, Sammy Sosa, and Mark McGuire that homerun standard has shifted. The same needs to happen with softball. Until now there was no real proof that technology has changed the game. Performances of both pitchers and hitters have been held to past players abilities. It has been very rare to see a player hit 20 plus homeruns in a season, while good pitching performances are expected to be under the 1.0 earned run average (number of runs on average a pitcher gives up per 7 innings). With the increase in offensive performance, specifically home runs, these parameters of performance need to be shifted. While this result of the data is not as important as injuries it is still part of the game, and a part that should still be addressed.

Conclusion

This study investigated the relationship between composite bat technology and 13 offensive statistics. In addition to bat technology it analyzed the relationship between ball Coefficient of Restitution and offensive statistics. The study included 28 NCAA Division I Louisville Slugger Sponsored programs from the 2002, 2003, 2004 and 2005 seasons. The results indicated that there was no effect for the change in COR, but that there was an effect for change in bat technology. Of the seven statistical categories utilized in the one-way ANOVA five of them returned a significant result and two did not. The results further indicated that the change in bat is significant in producing more home runs, higher slugging percentages, and better batting averages. The descriptive statistics indicated a dramatic increase in mean home runs and mean hits, with a 45% increase in mean homeruns in 2005.

APPENDIX A

Table 8
Websites for Participating Schools

Arizona State University	http://thesundevils.collegesports.com/sports/w-softbl/asu-w-softbl-body.html
Auburn University	http://www.auburntigers.com/softball/
University of Central Florida	http://ucfathletics.collegesports.com/sports/w-softbl/ucf-w-softbl-body.html
Central Michigan University	http://cmuchippewas.collegesports.com/sports/w-softbl/cmu-w-softbl-body.html
DePaul University	http://www.depaulbluedemons.com/sport.asp?CatID=10
University of Florida	http://www.gatorzone.com/softball/index.php
Hofstra University	http://www.hofstra.edu/Athletics/Softball/index_Softball.cfm
University of Illinois - Chicago	http://uicflames.collegesports.com/sports/w-softbl/ilch-w-softbl-body.html
University of Iowa	http://hawkeyesports.collegesports.com/sports/w-softbl/iowa-w-softbl-body.html
Long Beach State University	http://www.longbeachstate.com/bbo/wsoft/
University of Louisiana – Lafayette	http://www.ragincajuns.com/softball/softball.htm
University of Louisville	http://uoflsports.collegesports.com/sports/w-softbl/lou-w-softbl-body.html
University of Michigan	http://www.mgoblue.com/section_display.cfm?section_id=194&top=2&level=2
University of Nevada Las Vegas	http://unlvrebels.collegesports.com/sports/w-softbl/unlv-w-softbl-body.html
University of North Carolina	http://tarheelblue.collegesports.com/sports/w-softbl/unc-w-softbl-body.html
Northern Illinois University	http://www3.niu.edu/athletics/softball/index.html
Northwestern University	http://nusports.collegesports.com/sports/w-softbl/nw-w-softbl-body.html
Ohio State University	http://ohiostatebuckeyes.collegesports.com/sports/w-softbl/
University of Pacific	http://pacifictigers.collegesports.com/sports/w-softbl/paci-w-softbl-body.html
Penn State University	http://www.gopsusports.com/Softball/home.cfm
University of South Carolina	http://uscsports.collegesports.com/sports/w-softbl/scar-w-softbl-body.html
University of South	http://gobulls.usf.edu/Sports/sport.asp?i=12

Florida	
Stanford University	http://gostanford.collegesports.com/sports/w-softbl/
Stetson University	http://www.stetson.edu/athletics/softball/home.php
Syracuse University	http://www.suathletics.com/index.asp?path=softball
Texas A&M University	http://sports.tamu.edu/index.php?SID=WSB
Virginia Tech University	http://www.hokiesports.com/softball/
University of Wisconsin	http://www.uwbadgers.com/sport_news/sb/headlines/index.aspx

Table 9
Batting Average ANOVA results

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.007	3	.002	4.001	.010
Within Groups	.067	108	.001		
Total	.075	111			

Table 10
Batting Average Pairwise Comparisons

Dependent Variable: BA
Tukey HSD

(I) year	(J) year	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
2.00	3.00	.01496	.00668	.119	-.0025	.0324
	4.00	.01332	.00668	.197	-.0041	.0308
	5.00	-.00389	.00668	.937	-.0213	.0135
3.00	2.00	-.01496	.00668	.119	-.0324	.0025
	4.00	-.00164	.00668	.995	-.0191	.0158
	5.00	-.01886*	.00668	.029	-.0363	-.0014
4.00	2.00	-.01332	.00668	.197	-.0308	.0041
	3.00	.00164	.00668	.995	-.0158	.0191
	5.00	-.01721	.00668	.054	-.0346	.0002
5.00	2.00	.00389	.00668	.937	-.0135	.0213
	3.00	.01886*	.00668	.029	.0014	.0363
	4.00	.01721	.00668	.054	-.0002	.0346

*. The mean difference is significant at the .05 level.

Table 11
Slugging Percentage ANOVA results

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	41073.783	3	13691.261	3.900	.011
Within Groups	379096.597	108	3510.154		
Total	420170.379	111			

Table 12
Slugging Percentage Pairwise Comparison

Dependent Variable: SLG
Tukey HSD

(I) year	(J) year	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
2.00	3.00	22.80143	15.83431	.477	-18.5180	64.1208
	4.00	5.44429	15.83431	.986	-35.8751	46.7637
	5.00	-30.30571	15.83431	.228	-71.6251	11.0137
3.00	2.00	-22.80143	15.83431	.477	-64.1208	18.5180
	4.00	-17.35714	15.83431	.693	-58.6765	23.9622
	5.00	-53.10714*	15.83431	.006	-94.4265	-11.7878
4.00	2.00	-5.44429	15.83431	.986	-46.7637	35.8751
	3.00	17.35714	15.83431	.693	-23.9622	58.6765
	5.00	-35.75000	15.83431	.115	-77.0694	5.5694
5.00	2.00	30.30571	15.83431	.228	-11.0137	71.6251
	3.00	53.10714*	15.83431	.006	11.7878	94.4265
	4.00	35.75000	15.83431	.115	-5.5694	77.0694

*. The mean difference is significant at the .05 level.

Table 13
Batted Ball Hits Percentage ANOVA Results

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.018	3	.006	6.636	.000
Within Groups	.096	108	.001		
Total	.113	111			

Table 14
Batted Ball Hits Percentage Pairwise Comparison

Dependent Variable: BB_HITS
Tukey HSD

					95% Confidence Interval	
(I) year	(J) year	Mean Difference (I-J)	Std. Error	Sig.	Lower Bound	Upper Bound
2.00	3.00	.01411	.00795	.291	-.0066	.0349
	4.00	.01000	.00795	.592	-.0107	.0307
	5.00	-.01839	.00795	.101	-.0391	.0024
3.00	2.00	-.01411	.00795	.291	-.0349	.0066
	4.00	-.00411	.00795	.955	-.0249	.0166
	5.00	-.03250*	.00795	.000	-.0532	-.0118
4.00	2.00	-.01000	.00795	.592	-.0307	.0107
	3.00	.00411	.00795	.955	-.0166	.0249
	5.00	-.02839*	.00795	.003	-.0491	-.0076
5.00	2.00	.01839	.00795	.101	-.0024	.0391
	3.00	.03250*	.00795	.000	.0118	.0532
	4.00	.02839*	.00795	.003	.0076	.0491

*. The mean difference is significant at the .05 level.

Table 15
Batted Ball Singles Percentage ANOVA Results

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.006	3	.002	4.754	.004
Within Groups	.044	108	.000		
Total	.050	111			

Table 16
Batted Ball Singles Percentage Pairwise Comparisons

Dependent Variable: BB_1B
Tukey HSD

(I) year	(J) year	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
2.00	3.00	.01957*	.00541	.003	.0055	.0337
	4.00	.00550	.00541	.740	-.0086	.0196
	5.00	.00579	.00541	.709	-.0083	.0199
3.00	2.00	-.01957*	.00541	.003	-.0337	-.0055
	4.00	-.01407	.00541	.051	-.0282	.0000
	5.00	-.01379	.00541	.058	-.0279	.0003
4.00	2.00	-.00550	.00541	.740	-.0196	.0086
	3.00	.01407	.00541	.051	.0000	.0282
	5.00	.00029	.00541	1.000	-.0138	.0144
5.00	2.00	-.00579	.00541	.709	-.0199	.0083
	3.00	.01379	.00541	.058	-.0003	.0279
	4.00	-.00029	.00541	1.000	-.0144	.0138

*. The mean difference is significant at the .05 level.

Table 17
Batted Ball Doubles ANOVA Results

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.000	3	.000	1.630	.187
Within Groups	.011	108	.000		
Total	.011	111			

Table 18
Batted Ball Doubles Percentage Pairwise Comparisons

Dependent Variable: BB_DB
Tukey HSD

(I) year	(J) year	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
2.00	3.00	.00082	.00264	.990	-.0061	.0077
	4.00	.00211	.00264	.855	-.0048	.0090
	5.00	-.00346	.00264	.557	-.0104	.0034
3.00	2.00	-.00082	.00264	.990	-.0077	.0061
	4.00	.00129	.00264	.962	-.0056	.0082
	5.00	-.00429	.00264	.370	-.0112	.0026
4.00	2.00	-.00211	.00264	.855	-.0090	.0048
	3.00	-.00129	.00264	.962	-.0082	.0056
	5.00	-.00557	.00264	.156	-.0125	.0013
5.00	2.00	.00346	.00264	.557	-.0034	.0104
	3.00	.00429	.00264	.370	-.0026	.0112
	4.00	.00557	.00264	.156	-.0013	.0125

Table 19
Batted Ball Triples Percentage ANOVA Results

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.000	3	.000	1.245	.297
Within Groups	.006	108	.000		
Total	.006	111			

Table 20
Batted Ball Triples Percentage Pairwise Comparisons

Dependent Variable: BB_TP
Tukey HSD

(I) year	(J) year	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
2.00	3.00	-.00275	.00201	.523	-.0080	.0025
	4.00	.00100	.00201	.959	-.0042	.0063
	5.00	-.00050	.00201	.995	-.0057	.0048
3.00	2.00	.00275	.00201	.523	-.0025	.0080
	4.00	.00375	.00201	.249	-.0015	.0090
	5.00	.00225	.00201	.678	-.0030	.0075
4.00	2.00	-.00100	.00201	.959	-.0063	.0042
	3.00	-.00375	.00201	.249	-.0090	.0015
	5.00	-.00150	.00201	.878	-.0067	.0037
5.00	2.00	.00050	.00201	.995	-.0048	.0057
	3.00	-.00225	.00201	.678	-.0075	.0030
	4.00	.00150	.00201	.878	-.0037	.0067

Table 21
Batted Ball Homerun Percentage ANOVA Results

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.002	3	.001	6.188	.001
Within Groups	.014	108	.000		
Total	.016	111			

Table 22
Batted Ball Homerun Percentage Pairwise Comparisons

Dependent Variable: BB_HR
Tukey HSD

(I) year	(J) year	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
2.00	3.00	-.00286	.00301	.779	-.0107	.0050
	4.00	.00064	.00301	.997	-.0072	.0085
	5.00	-.01089*	.00301	.003	-.0188	-.0030
3.00	2.00	.00286	.00301	.779	-.0050	.0107
	4.00	.00350	.00301	.652	-.0044	.0114
	5.00	-.00804*	.00301	.043	-.0159	-.0002
4.00	2.00	-.00064	.00301	.997	-.0085	.0072
	3.00	-.00350	.00301	.652	-.0114	.0044
	5.00	-.01154*	.00301	.001	-.0194	-.0037
5.00	2.00	.01089*	.00301	.003	.0030	.0188
	3.00	.00804*	.00301	.043	.0002	.0159
	4.00	.01154*	.00301	.001	.0037	.0194

*. The mean difference is significant at the .05 level.

Table 23
Batted Ball Slugging Percentage ANOVA Results

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.079	3	.026	7.726	.000
Within Groups	.370	108	.003		
Total	.449	111			

Table 24
Batted Ball Slugging Percentage Pairwise Comparisons

Dependent Variable: BB_SLG
Tukey HSD

(I) year	(J) year	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
2.00	3.00	.00104	.01563	1.000	-.0398	.0418
	4.00	.01354	.01563	.822	-.0273	.0543
	5.00	-.05536*	.01563	.003	-.0962	-.0146
3.00	2.00	-.00104	.01563	1.000	-.0418	.0398
	4.00	.01250	.01563	.854	-.0283	.0533
	5.00	-.05639*	.01563	.003	-.0972	-.0156
4.00	2.00	-.01354	.01563	.822	-.0543	.0273
	3.00	-.01250	.01563	.854	-.0533	.0283
	5.00	-.06889*	.01563	.000	-.1097	-.0281
5.00	2.00	.05536*	.01563	.003	.0146	.0962
	3.00	.05639*	.01563	.003	.0156	.0972
	4.00	.06889*	.01563	.000	.0281	.1097

*. The mean difference is significant at the .05 level.

APPENDIX B

Figure 3
Mean HITS by Season

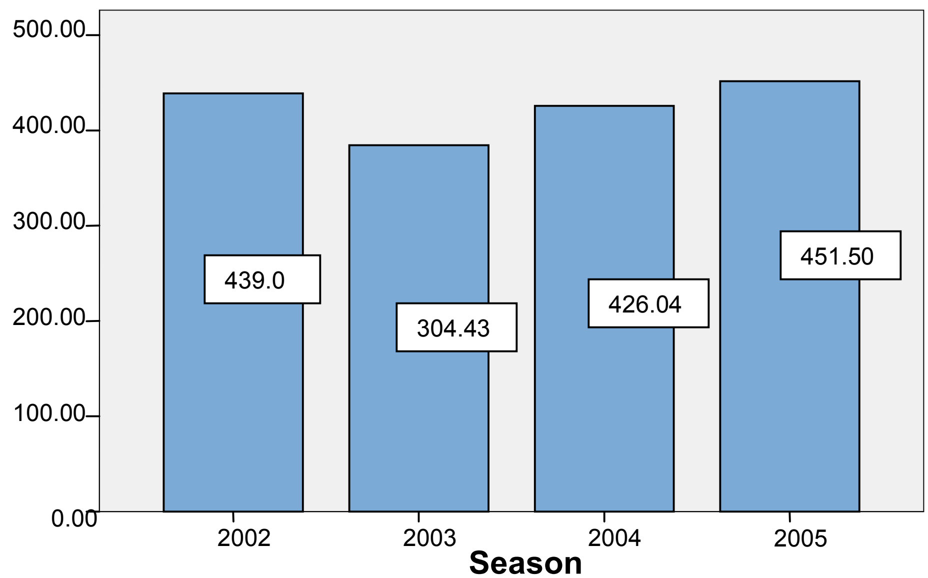


Figure 4
Mean RUNS by Season

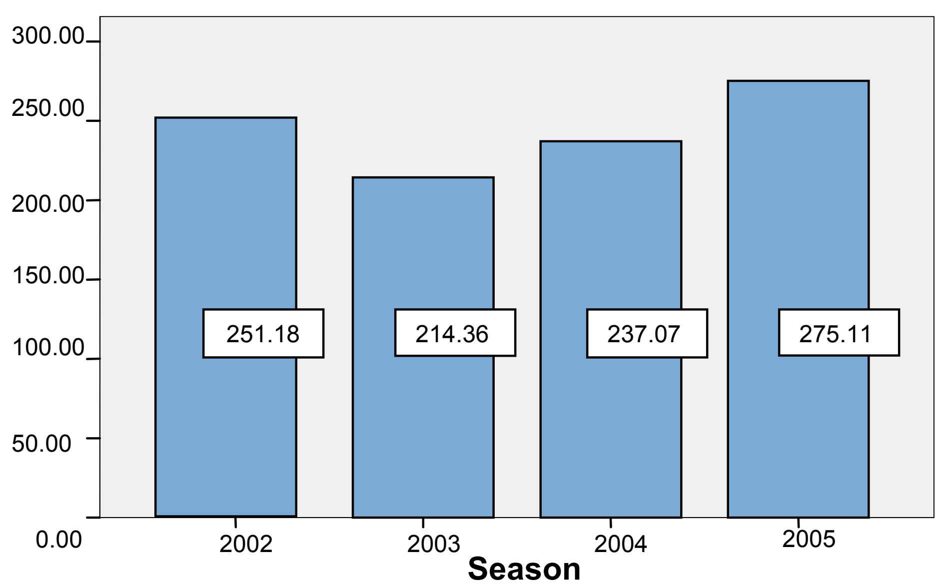


Figure 5
Mean SINGLES by Season

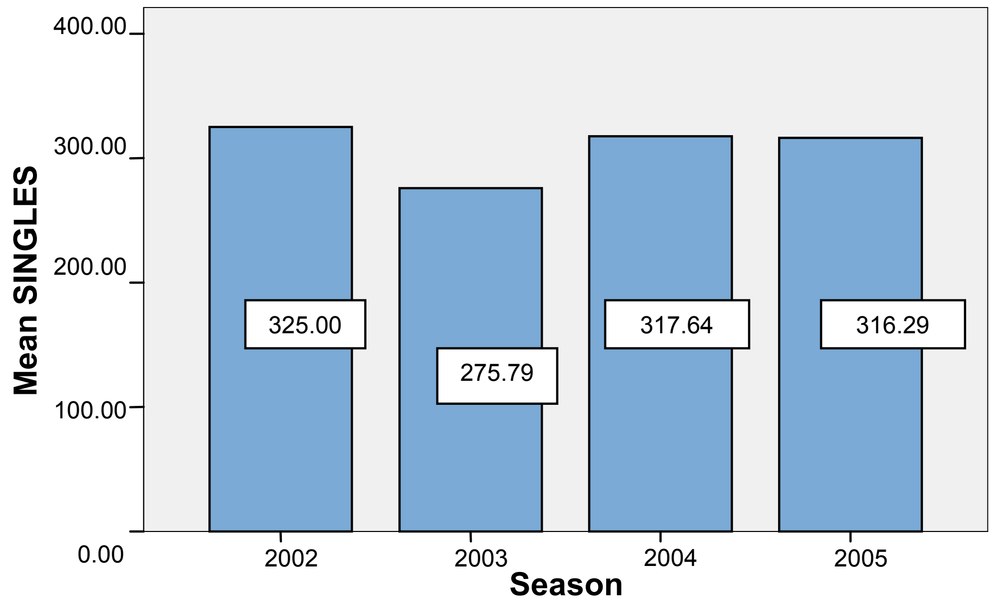


Figure 6
Mean DOUBLES by Season

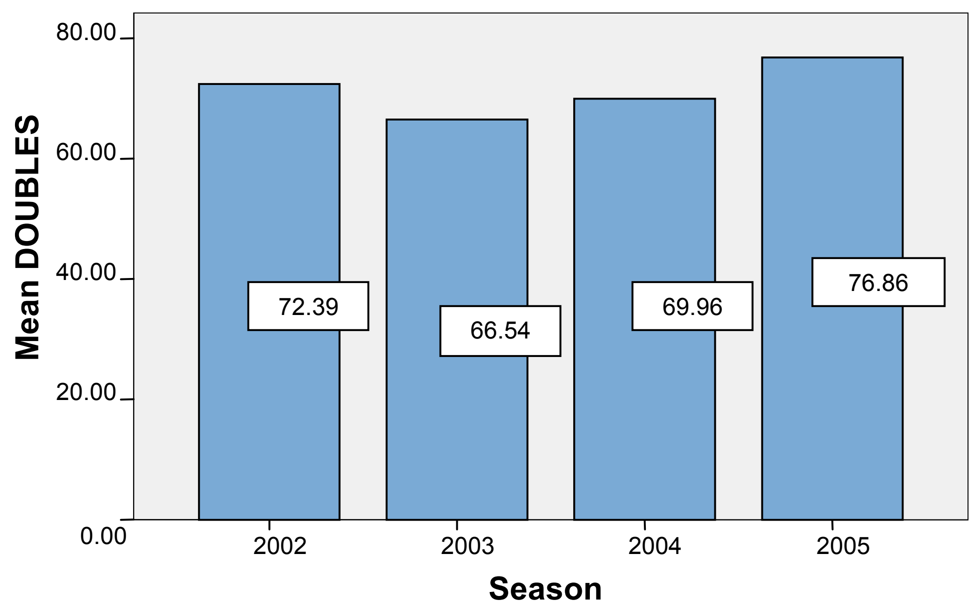
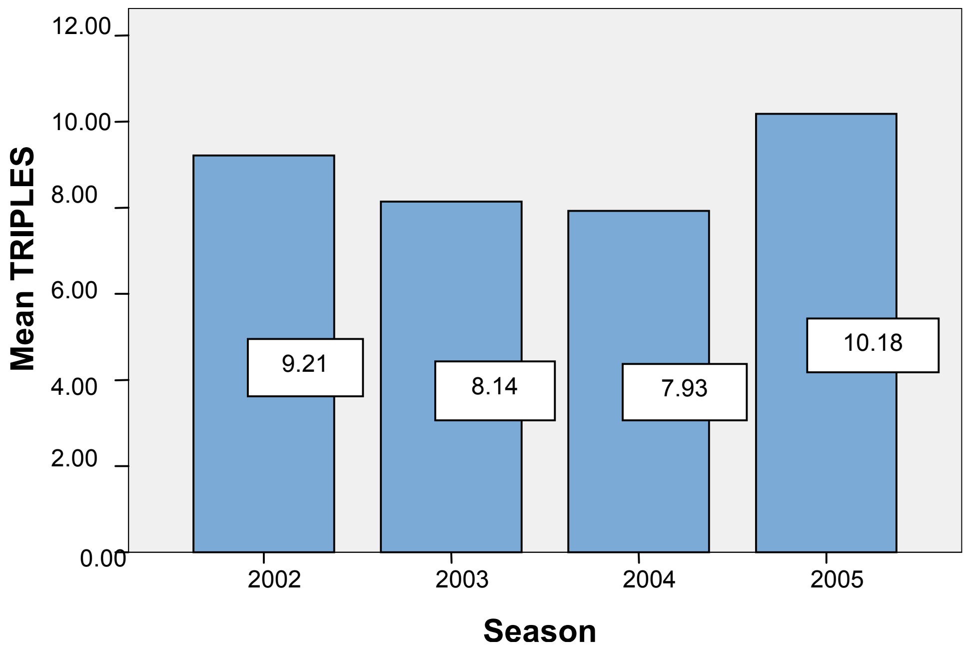


Figure 7
Mean TRIPLES by Season



APPENDIX C

Figure 8
Mean Batting Average by Season

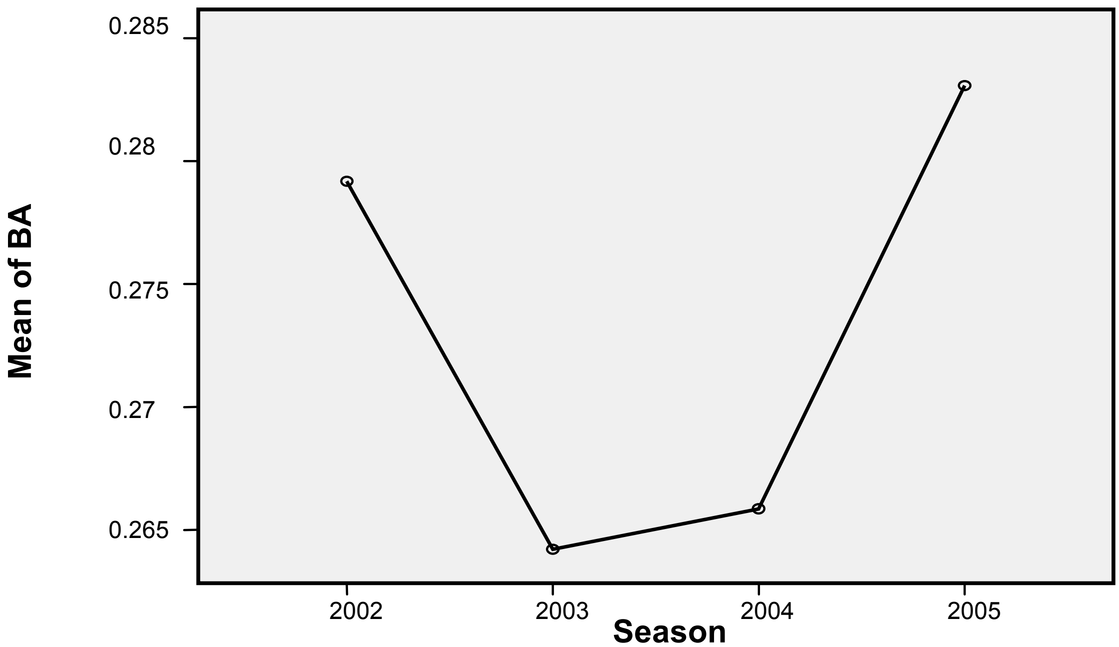


Figure 9
Mean Slugging Percentage by Season

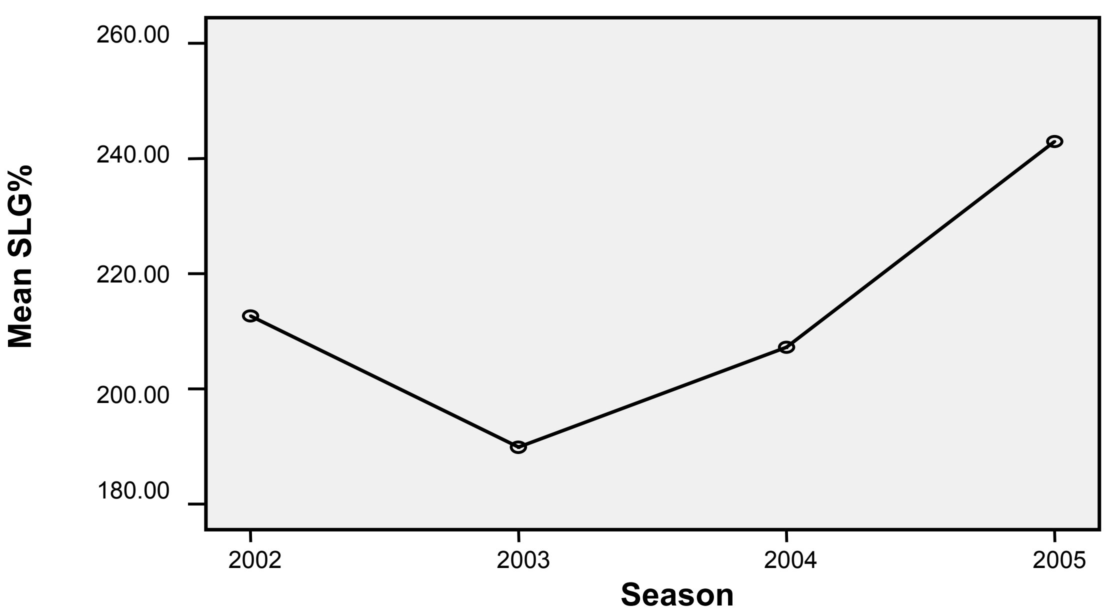


Figure 10
Mean Batted Ball HITS Percentage By Season

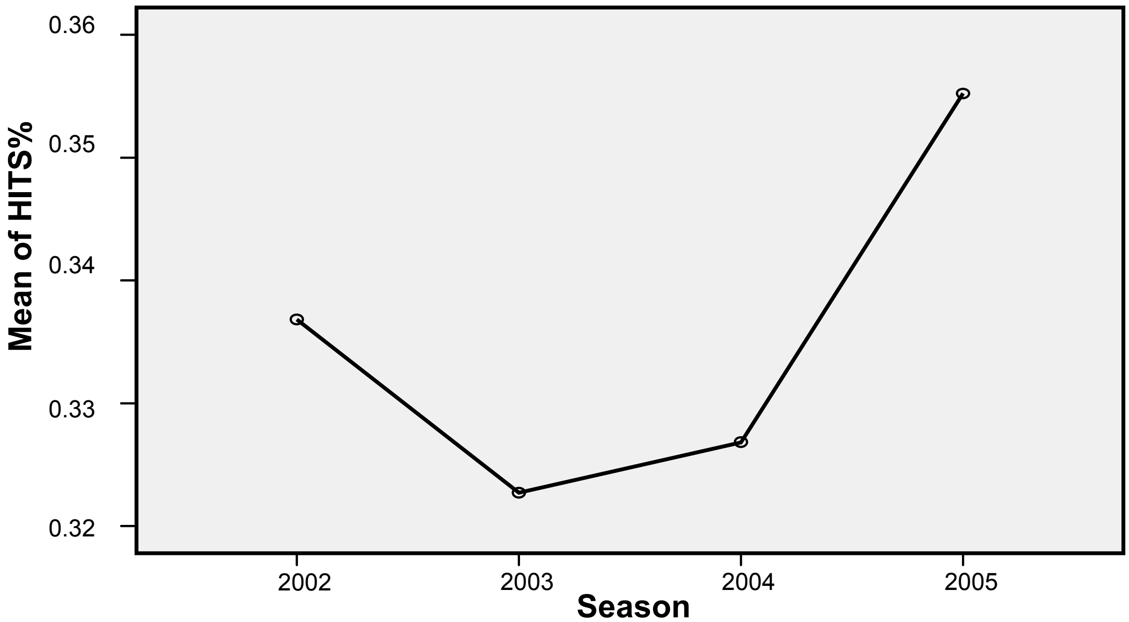


Figure 11
Batted Ball SINGLES Percentage by Season

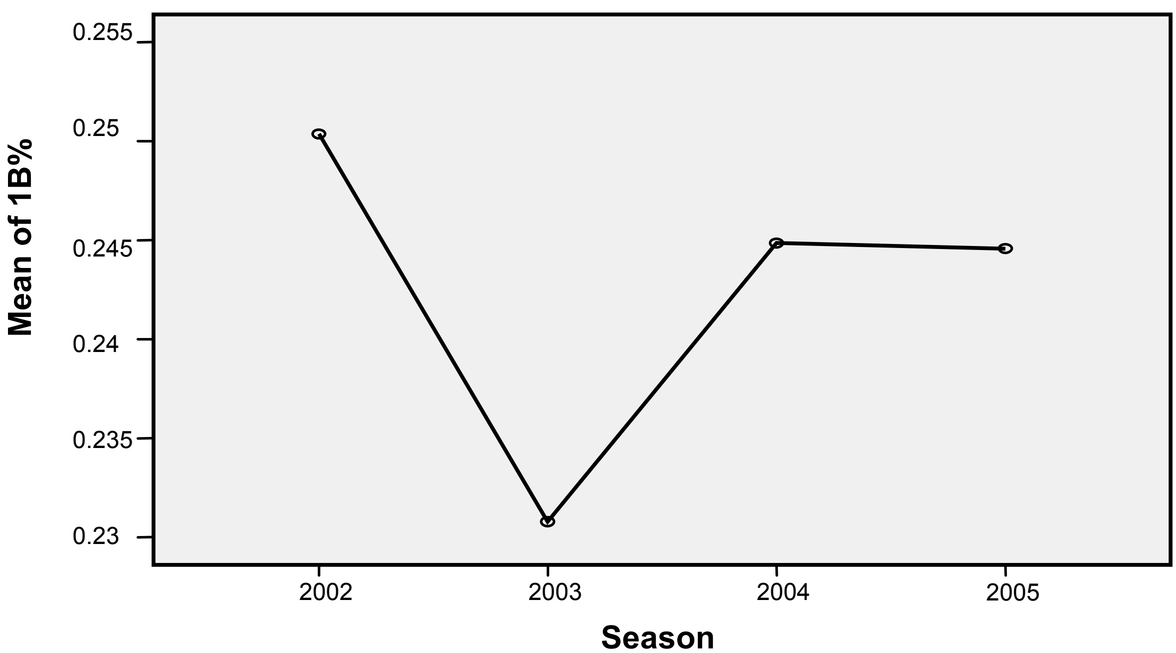


Figure 12
Mean of Batted Ball Doubles Percentage by Season

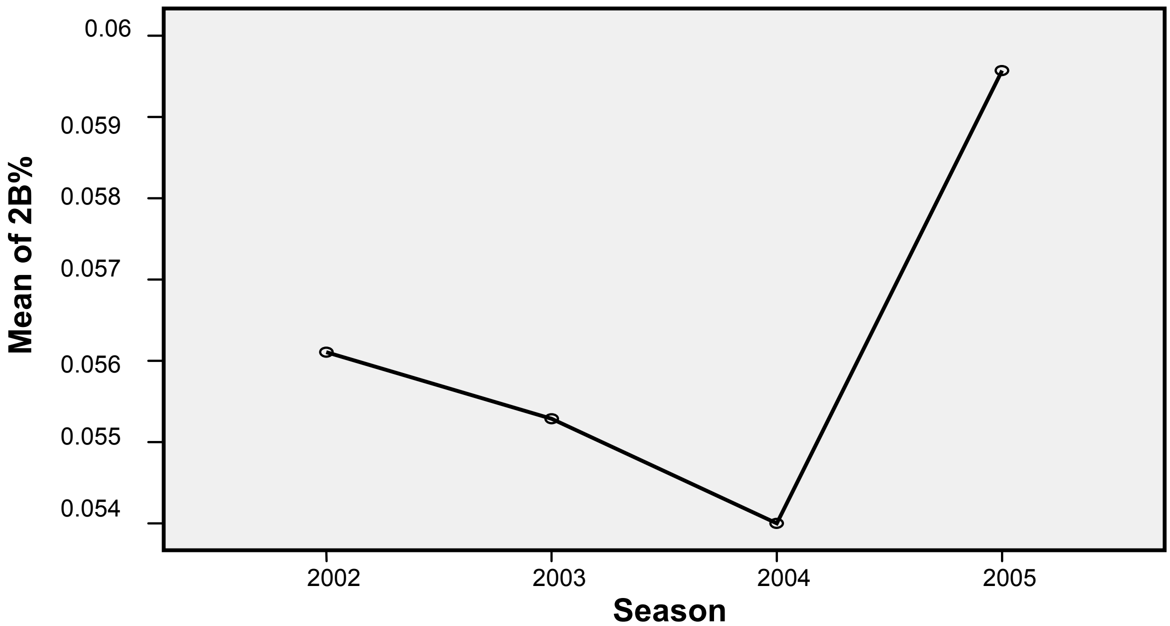


Figure 13
Batted Ball Triples Percentage

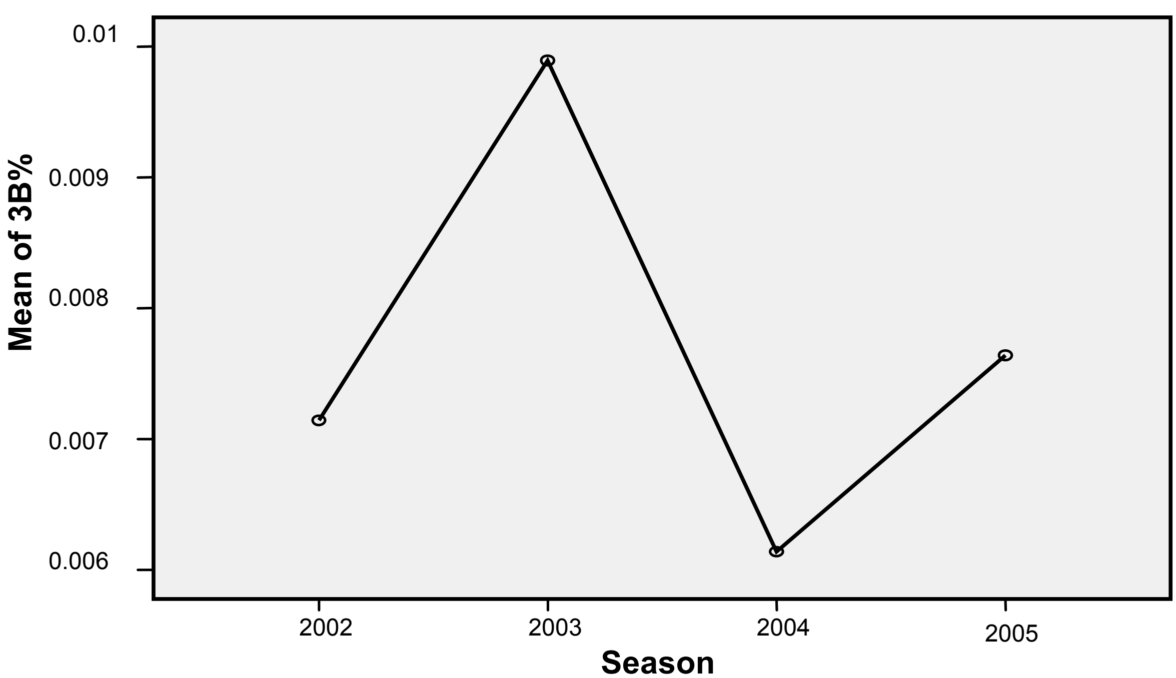


Figure 14
Batted Ball Homerun Percentage by Season

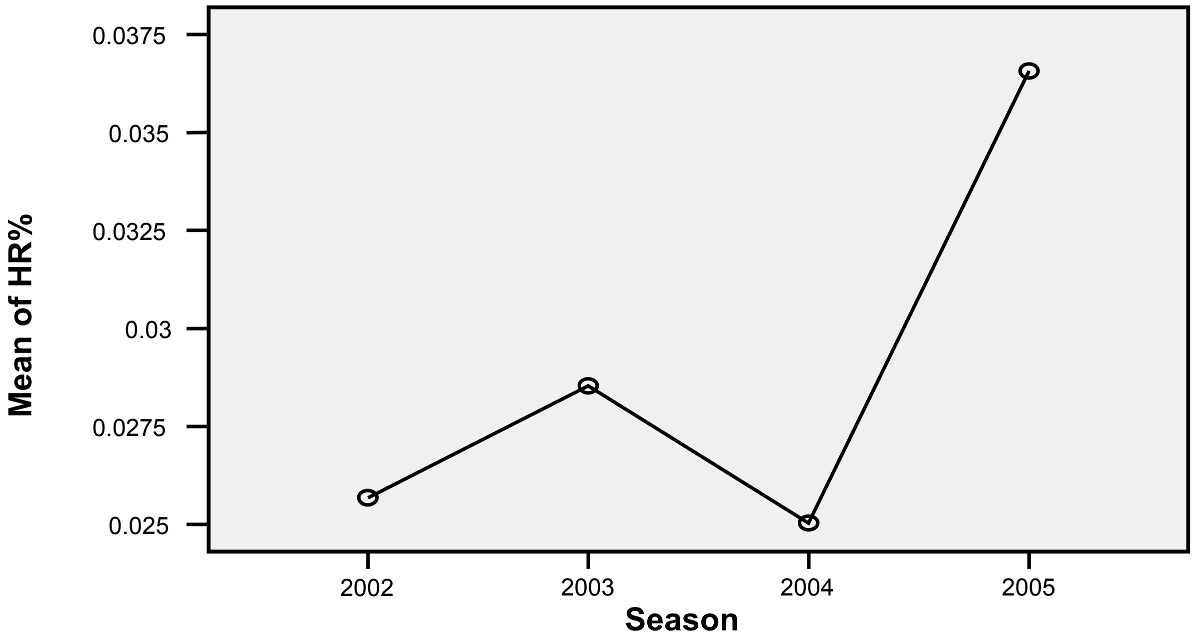
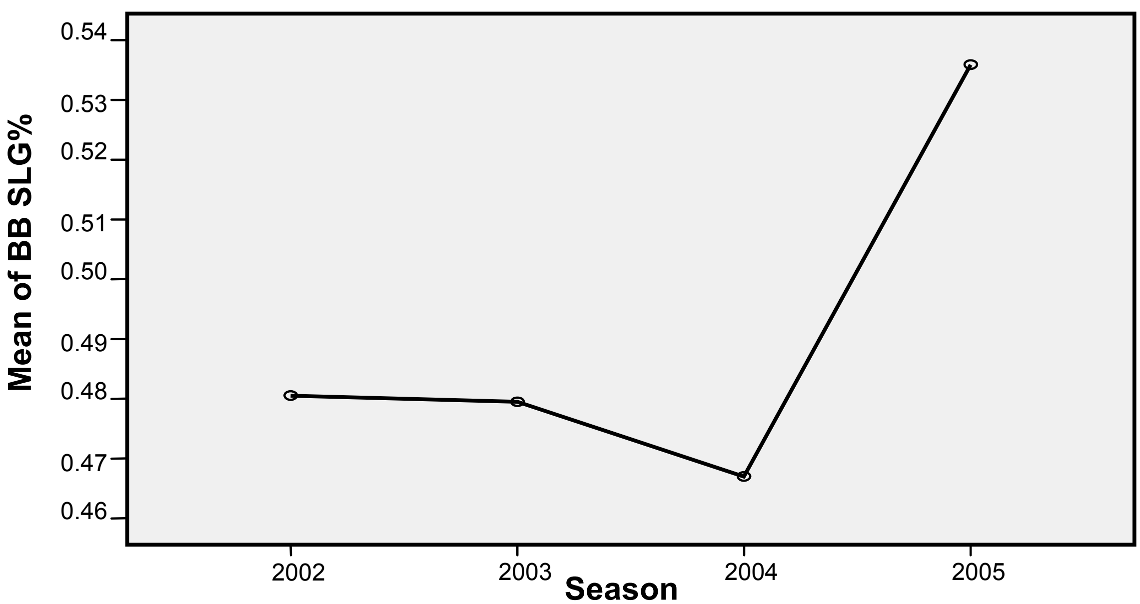


Figure 15
Batted Ball Slugging Percentage by Season



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