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Baseball studies: baseball bat testing protocol development

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Abstract

The performance testing of baseball bats for potential use in regulating bat performance is best completed using the same baseballs as are used in a game. In the current research, the effects of repeated use of baseballs in testing are explored. The bat-ball performance is compared with ball performance off a rigid wall, and the consistency of both bat- and ball-performance metrics during bat-ball testing. The understanding of these conditions gives bat testers and regulatory bodies a basis for what test criteria to consider in the development of baseball bat test protocols.

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1. Introduction

Sports governing bodies often must regulate the equipment used in their games with lab tests that simulate game conditions and incorporate the use of two objects; the object being evaluated and the object that it impacts in the course of its use, e.g. a baseball bat performance test requiring the use of a baseball. Over the past decade, baseballs have been used to test baseball bats. Due to concerns that the performance of the baseball can degrade with repeated use, the number of times that a baseball could be used was limited to a few impacts before the baseball was deemed to be questionable for further testing and hence was discarded. In the current research, the effects of repeated use of baseballs in testing are explored, a comparison of bat-ball performance to ball performance off a rigid wall is performed, and an investigation of the consistency of both bat-performance metrics and ball-performance metrics during bat-ball testing is undertaken. The understanding of these conditions gives regulatory bodies and test operators a basis for what test criteria to consider in the development of baseball bat test protocols.

The National Collegiate Athletic Association (NCAA) governs collegiate baseball in the U.S., and their baseball bat testing program is the predominant program for testing and certification of baseball bats for adult-level amateur baseball. First established in 1999, the Ball Exit Speed Ratio (BESR) [1] testing protocol was applied to certify nonwood bats. To be certified as compliant with the performance standard, the nonwood bats had to exhibit a performance level at or below a limit that was determined from the same type of testing with solid wood baseball bats. The protocol specified the use of the NCAA championship baseball for all testing and specified an acceptable weight range for the baseball of 144.4 to 146.4 grams (5.094 to 5.164 oz). The protocol then specified that baseballs from the lot be tested using a standard bat for ball lot calibration purposes. The data collected from the testing of the

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baseballs was then used to offset any differences between the average performances of two baseball lots. At that time, a baseball was limited to one hit per day to allow time for the baseball to recover from the impact. To remove any concern that the liveliness of the baseball could change with use, each test ball was limited to a maximum of eight impacts before it was removed from the test program. The baseballs were restricted to this limited use based on a desire for the consistent baseball performance over the use of each baseball and the entire lot of baseballs used in the testing. A typical baseball lot was between 100 and 160 baseballs to allow for testing throughout the day.

Over the past decade, the research and testing has given the opportunity to collect a large quantity of data from the bat testing process. The NCAA has implemented protocol revisions and new testing protocols as more data give added insight to the testing capabilities and the range of designs for bats. In 2007, the NCAA moved from the standard bat that was selected in 1999 to using a thick-wall aluminum bat as the standard bat. The aluminum bat introduced improved consistency among different standard bats for ball-lot preparation. In addition, the aluminum standard bat has a much longer useful life (~2000 hits) than the initial standard bat (~300 hits). In 2008 and 2009, additional research was performed to further understand the effect of baseballs used in the bat testing protocols and to contribute to the development of a new Bat-Ball Coefficient of Restitution (BBCOR) protocol [2].

This paper will present the results of three areas of interest with respect to baseball performance. The first topic discusses the effects of repeated impacts on a baseball. Both a recovery time of just minutes and a recovery time of a day or more were investigated. The second topic analyzes results of studies into the consistency of two bat performance metrics, i.e. Ball Exit Speed Ratio (BESR) and Bat-Ball Coefficient of Restitution (BBCOR) on solid-barrel bats and collegiate baseballs. The third topic studies the measured BBCOR values using a thick-wall aluminum bat to the ball performance metrics of Coefficient of Restitution (COR) [3] and Cylindrical Coefficient of Restitution (CCOR) [4]. These three topics further the understanding of the components of any standardized baseball-bat testing and assist with the development of a new test protocol. The information gained from this research may have applications to other sporting areas, e.g. cricket.

2. Procedures

The development of a baseball bat testing protocol requires a good understanding of how the baseballs change or remain unchanged with repeated use. The procedures used to investigate the baseball contribution to the bat testing are described in this section. There are three main topics examined; the influence of repeated impacts on the performance of baseballs, the consistency of performance metrics resulting from a specified lot of baseballs of the same model, and the relationship among BBCOR, COR and CCOR. The BBCOR is a bat-ball performance metric, and COR and CCOR are baseball performance metrics. All tests used the NCAA Bat Certification Protocol [5] and ASTM standards, F1887 [3], and F2219 [6], as a basis of the test conditions. All of the baseballs were stored and the tests performed in a laboratory environment of 22.2 ± 2.2 °C (72 ± 4 °F) and 50% relative humidity.

2.1. The influence of repeated impacts on the performance of a baseball

Baseballs for bat testing are impacted multiple times and are expected to have essentially the same performance each time they are used to achieve meaningful data. Therefore, most testing limits the number of impacts for each baseball in an effort to ensure that the baseball properties are not given the opportunity to change appreciably. Dynamic impacts also have a time dependence that can affect the recovery of the ball properties. Therefore, most testing standards have a required rest period between each use. Two long-standing test methods that specify the use and rest periods for baseballs are ASTM F1887, Coefficient of Restitution, and the NCAA Bat Testing Protocol. The ASTM COR standard specifies an impact velocity of 60 ± 0.68 mph (26.82 ± 0.30 m/s), a rest period of at least 30 seconds and no more than 12 total impacts to achieve the six valid impacts required to calculate the COR. The NCAA baseball bat BESR protocol requires an impact velocity of 136 ± 2 mph (60.80 ± 0.89 m/s), no more than one impact per day per baseball, and no more than eight total impacts on any baseball.

This study investigated both the number of impacts and the rest period for a baseball used in baseball bat testing at 136 mph (60.80 m/s). Two different methods were utilized, one studying the effect with a short rest period of approximately one minute and the other with a rest period of a day. The baseballs used for both methods were Rawlings R1NCAA, the same ball specified in NCAA BESR testing protocol. The first method consisted of baseballs being fired a total of 50 times with a one-minute rest period between impacts. The baseballs were fired at

a solid wood barrel bat with an impact speed of 136 ± 2 mph (60.80 ± 0.89 m/s). The second method consisted of baseballs being fired at the same impact speed and against the same solid wood barrel bat. This second method exposed the baseballs to 25 total impacts but with a minimum rest period of one day. Only impacts valid according to the NCAA Bat Testing Protocol are included in the analysis.

2.2. Consistency of bat performance metrics using baseballs from one production and meeting test requirements

The NCAA Bat Certification protocol specifies the baseball model R1NCAA, which is the NCAA Championship baseball. The R1NCAA baseball is a standard wool-wound baseball sold by Rawlings Sporting Goods. The consistency of the construction of the baseball is important for the game and for the bat certification process. The BESR certification protocol calculates a single value for the liveliness of each lot of baseballs used for testing the performance of each bat, and the current BESR protocol consists of 30 valid hits on the standard bat to characterize the overall performance of the lot consisting of 120 to 160 baseballs. The standard bat used in the BESR protocol and this research is a thick-wall aluminum bat. This research was conducted to determine if 30 hits is an adequate number of hits to properly characterize the performance of the lot. Four simulated ball-lot preparations were conducted on a baseball lot consisting of 120 baseballs using a standard bat. Each ball-lot preparation consisted of 30 valid hits at the 6-inch (15.24-cm) location on the bat as measured from the tip of the barrel. The BESR and BBCOR values were recorded for each hit. Comparisons were made among the average results of the four test series. Larger and smaller sample sizes were also investigated from full data set.

2.3. Measuring the relationship between baseball performance metrics: BBCOR vs. CCOR and COR

Three different test methods were used to test individual baseballs for the third study. The BBCOR, CCOR and COR were measured on the same 38 baseballs, such that the values could be compared. The set of 38 baseballs consisted of a variety of models and a combination of both new and previously used baseballs. A majority of the baseballs were Rawlings Model R1NCAA baseballs, but other baseball makes and models were also included to expand the range of values observed for the different metrics, e.g. lower and higher BBCOR baseballs.

Each of the 38 baseballs was BBCOR tested at the 5.5-inch (13.97-cm) location on a bat with a solid maple barrel with a 137.5-mph (61.47-m/s) impact velocity. The 5.5-inch (13.97 cm) location had previously been identified as the sweet spot location on the bat, and the 137.5-mph (61.47-m/s) velocity was selected per the standard NCAA Bat Testing Protocol [1]. Originally the set of baseballs included only 36, but more baseballs were added to the sample in an effort to achieve a BBCOR range of ~ 0.050 . Each ball was hit only once per day. After three cycles of BBCOR testing, CCOR testing was conducted. CCOR testing was conducted at 115 ± 1 mph (51.41 ± 0.45 m/s) with a steel cylindrical impact surface using a test machine that is capable of measuring dynamic stiffness. The dynamic stiffness machine utilizes an air cannon that fires baseballs within plus or minus one mph (0.23 m/s) of the prescribed velocity and without spin. The machine is also capable propelling the ball with precise targeting allowing for the ball to rebound without an angular change from a cylindrical impact surface and measuring the velocities very accurately with multiple sets of light gates. Six shots were taken with each ball. BBCOR testing of one impact per day resumed the following day. After each ball received six valid BBCOR shots, COR testing was conducted at 60 ± 1 mph (26.82 ± 0.45 m/s) against a flat steel impact surface using the dynamic stiffness machine and acquiring six valid impacts.

3. Results

The results reported in this paper are presented primarily in terms of the standard performance metric of COR, but also in several different forms as appropriate for exploring the data. Traditional COR is the ball performance metric that incorporates a baseball being fired at a rigid flat wall. These tests are performed at 60 mph (26.82 m/s) according to ASTM standard F1881. The CCOR tests incorporate a baseball being fired at 115 mph (51.41 m/s) at a rigid cylindrical surface with a 2.625-inch (66.68-mm) diameter. The BBCOR tests incorporate a baseball being fired at a stationary baseball bat that is free to swing after the impact. The impact velocity in the BBCOR test is 136 mph (60.80 m/s).

3.1. The influence of repeated impacts on the performance of a baseball

Performance testing results for repeated impacts on a single baseball are displayed in this section. Two different conditions were investigated.

The first condition exposed three different baseballs to 50 impacts each and a rest period of about one minute between impacts. This one-minute rest period was to mimic a worst-case situation for a baseball being used in a laboratory bat-testing protocol. Figure 1 shows the BESR and BBCOR results, respectively, for one of the three baseballs. The linear regression trend line in each plot shows an observable decrease in performance over these 50 impacts. The decrease in performance observed as a result of this repeated impacting for the baseball shown in Fig. 1 was about 0.007 in BESR and 0.011 in BBCOR. The other two baseballs had slightly less decreases in performance of 0.005 and 0.004 in BESR and 0.007 and 0.005 in BBCOR. On average, these values correlate to about a 1-mph decrease on a 100-mph batted-ball speed, a 1% decrease, which could significantly affect the outcome of a certification test. Similar trends are observed for both BESR (Fig. 1a) and BBCOR (Fig. 1b).

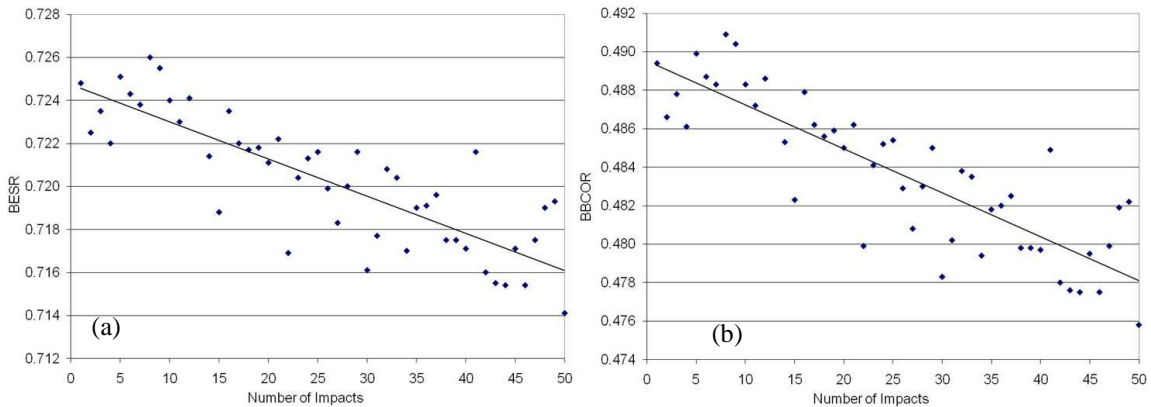


Fig. 1 Performance results of repeated impacts on a single baseball – one minute rest period (a) BESR (b) BBCOR

The second condition subjected four baseballs to 25 impacts with a rest period of at least one day between each impact. This rest period is the same currently used in the NCAA BESR Bat Certification Protocol. Figure 2 shows the results of these four baseballs. For a visual interpretation of the data, the data points for each baseball are connected with lines. Any gaps in the lines are the result of an invalid hit per the specified procedure, and therefore, those data are omitted from the plots because the data would potentially be unreliable. These data do not show a significant change in performance over the 25 impacts. The study of these two conditions, i.e. one-minute vs. one-day rest period, shows that the rest period between hits has a greater significance than the total number of hits on the baseball over the range studied.

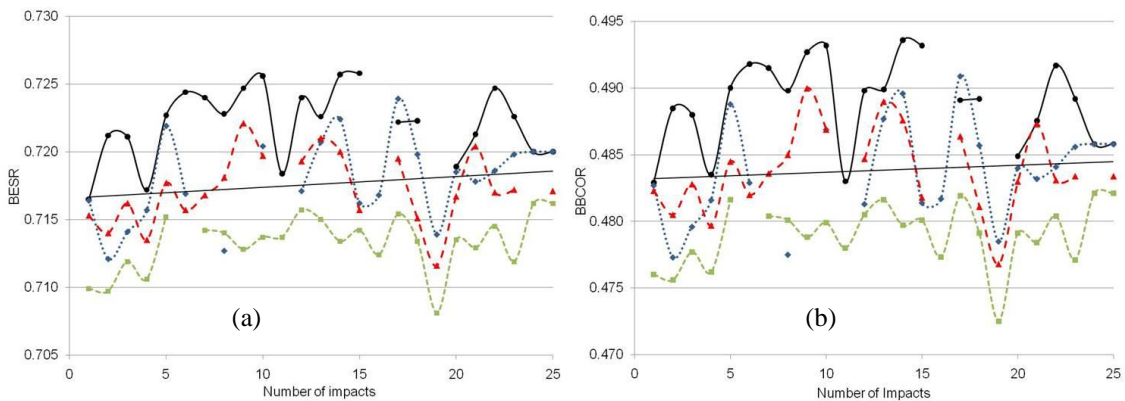


Fig. 2 Performance results of repeated impacts of four baseballs – one day rest period (a) BESR (b) BBCOR.

3.2. Consistency of bat performance metrics using baseballs from one production and meeting test requirements

A baseball lot consisting of 120 baseballs from a single shipment and production run were used for this testing. The entire set of baseballs was also stored in the same laboratory conditions since arrival to the laboratory. Each baseball in the lot was required to conform to the weights specified in BESR Bat Certification Protocol of 144.4 to 146.4 grams. Each baseball was tested until a valid hit was obtained during the performance testing. The results of those tests are displayed in Fig. 3. Figure 3a shows the BESR results, and Fig. 3b shows the BBCOR results. In both plots, each data point is plotted and then groups of data are presented by averages and confidence intervals representing 2x the standard deviation of the mean of each data set. The data are divided into groups consisting of 12, 30, 60 and the entire 120 hits. In terms of BESR, the range of individual values was about 0.026 from the lowest to the highest value within the lot. The overall average BESR was 0.732, and the average of the 30-hit groupings ranged from only 0.731 to 0.734. In terms of BBCOR, the overall average for the entire lot was 0.528 and the average 30-hit groupings ranged from 0.527 to 0.530. The data show the average lot value to be determined with a level of confidence of about 0.001 to 0.002 in both BESR and BBCOR when the sample size is at least 30 hits. The plots also show that the larger the sample size the smaller the confidence intervals that represent values 2x greater than the standard deviation of the mean.

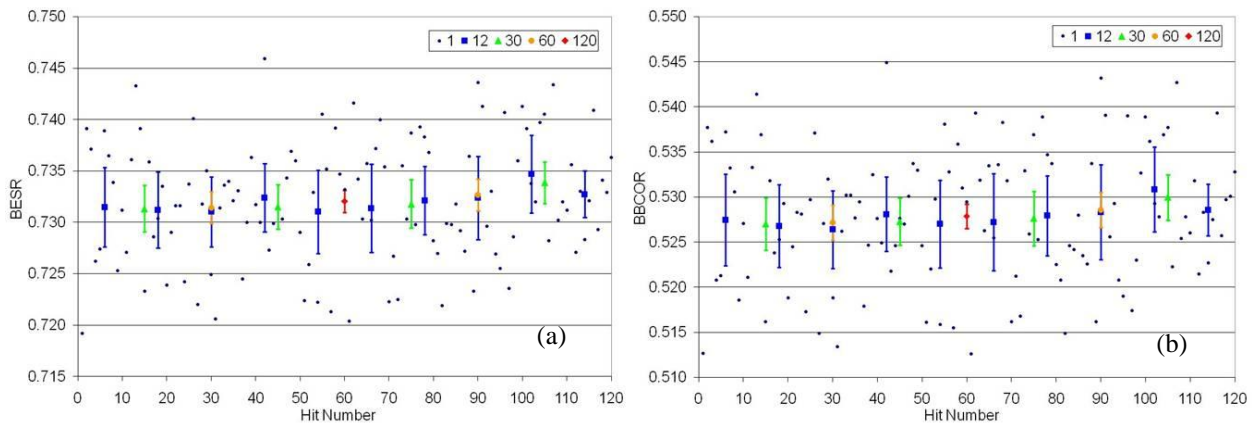


Fig. 3 (a) BESR and (b) BBCOR results from performance testing an entire lot consisting of 120 baseballs

3.3. Measuring the relationship between baseball performance metrics: BBCOR vs. CCOR and COR

The BBCOR, COR and CCOR values were measured for 38 baseballs. The data are presented in Fig. 4. In Fig. 4a, the COR is plotted against the BBCOR data on the same baseballs, and over the tested range, the data follow a linear trend. Figure 4b shows the CCOR values plotted against the BBCOR values for the same 38 baseballs, and there is also a linear trend observed. An overall observation of both data sets shows a much better correlation between CCOR at 115 mph and BBCOR at 136 mph than between COR at 60 mph and the same 136-mph BBCOR data. Figure 4b also shows that the CCOR at 115 mph and BBCOR at 136 mph have similar values with the CCOR at 115 mph being about 0.010 higher than the BBCOR value at 136 mph. The ranges of values for COR, CCOR and BBCOR are all about 0.040 for the sample of baseballs used in this study. These different Coefficient of Restitution values using different impact speeds and surfaces are related and in general have a numerical difference in relation to one another. The confidence intervals shown in both plots represent a single standard deviation of the mean based on the individual data of both measurements that contribute to these plots.

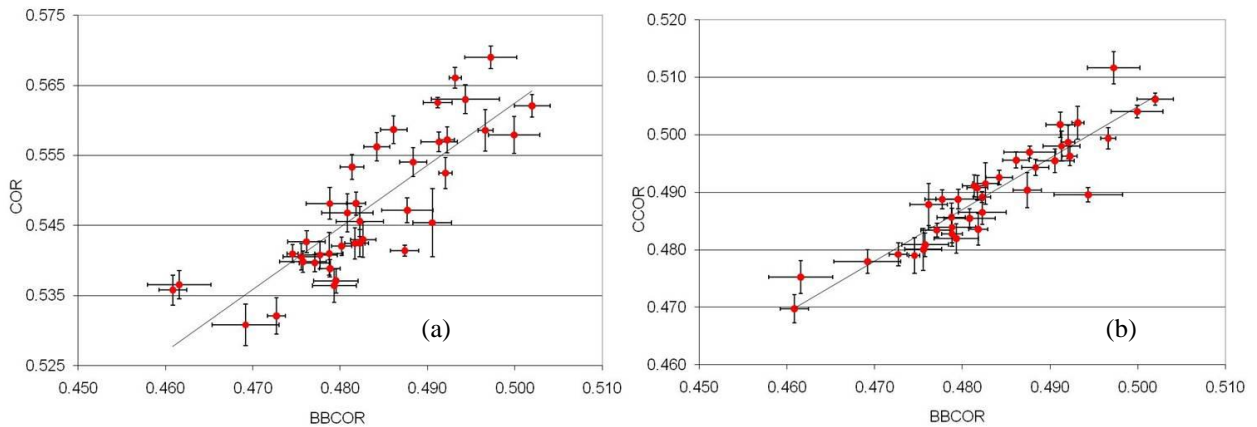


Fig. 4 (a) COR and (b) CCOR versus BBCOR for a range of ball performances

4. Conclusions

The development of baseball bat testing protocols requires a good understanding of the effect that baseball performance can have on the test results. The research presented in this paper studied how the number of impacts and rest period influence the performance of the baseball. With a very short rest period between impacts, the ball performance can decrease about 1%. However, with a rest period of a day, the performance shows no sign of observable change. Baseballs are not only fairly consistent performing over their useful life if given a rest period, but with a sufficient sample size of baseballs that meet the test specifications, the performance of the lot is also fairly consistent. Thirty valid hits were demonstrated to capture the overall performance of the lot within about 0.002 in both BESR and BBCOR. The relationship between BBCOR and the ball performance metrics, COR and CCOR, were investigated and demonstrated a correlation. The correlation demonstrated by CCOR was much better than with COR.

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References

- [1] NCAA, 1999, *National Collegiate Athletic Association Standard For Testing Baseball Bat Performance*, NCAA, Indianapolis, IN, 1999, Appendix in Thesis, Drane, 2003, *Characterization of the Effects of Use and Moisture Content on Baseball Bat Performance using Experimental Methods*, Appendix A.
- [2] NCAA, 2009, *National Collegiate Athletic Association Standard For Testing Baseball Bat Performance: BBCOR*, Indianapolis, IN, 2009, http://www.ncaa.org/wps/portal/ncaahome?WCM_GLOBAL_CONTEXT=/ncaa/ncaa/sports+and+championship/baseball/bat+standards/index.html.
- [3] ASTM Standard F1887, 2009, *Standard Test Method for Measuring the Coefficient of Restitution (COR) of Baseballs and Softballs*, ASTM International, West Conshohocken, PA, 2009, www.astm.org.
- [4] ASTM Draft Standard, 2010, *Standard Test Method for Measuring the Dynamic Stiffness (DS) and Cylindrical Coefficient of Restitution (CCOR) of Baseballs and Softballs*, ASTM International, West Conshohocken, PA, Not Publicly Available, www.astm.org.
- [5] NCAA, 2009, *National Collegiate Athletic Association Standard For Testing Baseball Bat Performance*, NCAA, Indianapolis, IN, 2009, http://www.ncaa.org/wps/portal/ncaahome?WCM_GLOBAL_CONTEXT=/ncaa/ncaa/sports+and+championship/baseball/bat+standards/index.html.
- [6] ASTM Standard F2219, 2009, *Standard Test Methods for Measuring High-Speed Bat Performance*, ASTM International, West Conshohocken, PA, 2009, www.astm.org.