# Characterization of the effect of temperature on baseball COR performance

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***ABSTRACT:*** In the game of baseball, the bat-ball collision is of great interest to both the fan and the scientist. The performance of baseball bats has been investigated and while there are plenty of ways of changing their performance, bats do not perform significantly different under different climate conditions. Baseballs, being made of a combination of cowhide, yarn and rubber, can change weight when exposed to a different humidity, which in turn can result in a change in performance of its collision with a bat. Additionally, during the course of a year, baseballs are exposed to a variety of outdoor temperatures. This paper will discuss the effect of temperature on the performance of a standard collegiate baseball. Using standard- and high-speed COR testing methods, the effect of both heating and cooling of a baseball will be investigated. The results from the standard COR test show that there is only a slight increase in performance with the heating of a baseball to an elevated temperature beyond the extreme of what would be experienced in normal play. There is a much more significant change in performance when a baseball is cooled. The performance decrease can be as much as 4% when the ball is subjected to subfreezing temperatures. The results of this study will help the scientific spectator understand how the game might change under different temperature conditions.

## INTRODUCTION

Researchers (Adair, 1994; Nathan, 2000; Shenoy *et al*., 2001) have been working to understand the bat-ball collision and measure performance of baseball bats. Some research has been performed on factors that affect the performance of baseball bats. There are also a number of factors that affect the performance of the baseballs, because there are a number of different components to the construction of a baseball. Fig. 1 shows the cross-section of an NCAA baseball and identifies the component layers. As shown in Fig. 1, these baseballs are constructed primarily of wool windings. The center of the ball, called the pill, has several layers of rubber surrounding a cork center. The mechanical behavior properties of wool can be affected by changes in moisture content that leads to a change in weight. The hyperelastic properties of the pill can change with temperature. This paper will investigate the effect of temperature on COR performance for a standard NCAA baseball.

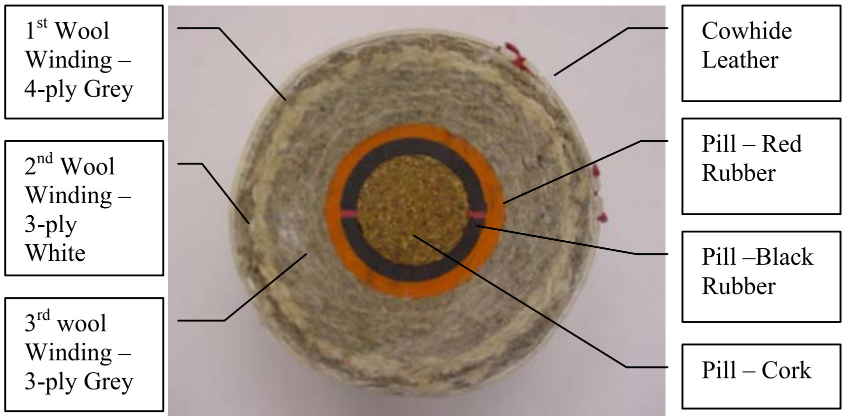


*Fig. 1* Cross-section of a standard NCAA baseball.

The measure of the performance of a baseball is Coefficient of Restitution (COR). The COR of a ball is calculated using Eq. 1, where $V_{inbound}$ is the speed of the ball being fired into a solid wood block and $V_{rebound}$ is the speed of the ball after it has hit the wood block.

$$COR = \frac{-V_{rebound}}{V_{inbound}} \tag{1}$$

The American Society for Testing and Materials (ASTM) test for COR is performed at a velocity of 60 mph (ASTM, 1998). The effect of temperature on baseball COR may differ at different collision velocities. Therefore, this study was conducted at two different ranges of velocity. The first velocity range is the one stated in the ASTM test for COR. The second velocity range more closely resembles the velocities of collision during field conditions.

**METHODOLOGY**

For this research, the effect of temperature on baseball COR was investigated using two velocity conditions and four temperature conditions. Two velocity conditions were employed to identify if the magnitude or trend of effect due to temperature would differ under different impact velocities. The baseline temperature for COR testing is 70°F lab conditions. Three other temperatures were chosen, refrigeration (40°F), subfreezing (25°F) and heating (120°F). This section will describe how the average COR of a set of baseballs was measured for each of these temperatures and the process that was used to condition the baseballs to the four temperatures.

### *COR Testing Methods*

The first test method, referred to as the Standard Method, used for measuring the COR of the baseballs was ASTM 1887-98, entitled "Standard Test Method for Measuring the Coefficient of Restitution (COR) of Baseballs and Softballs". The other method, referred to as the High Speed Method, used ASTM 1887-98 as a basis. ASTM 1887-98 requires that a baseball be fired from a distance of 8 ft from the wall at a velocity of 88±1 ft/s (60±0.6 mph). The velocity is measured using photogates that are located 12 in and 24 in from the 4-in thick northern white ash block. Each baseball is impacted against the block enough times to obtain 6 hits that are in the acceptable inbound velocity range without exceeding 12 ball impacts. The first method used for this study employed all of these requirements with the exception of not exceeding 12 ball impacts. Each baseball is tested under the four temperature conditions; therefore, each baseball needs 24 valid hits over the course of the testing, exceeding the maximum of 12 impacts on each baseball.

A previous and unpublished study performed at the Baseball Research Center showed that impacting a baseball more than 12 times does not show any significant effect in its COR performance if given the required 30-s recovery time between impacts. The results of this study are presented in Fig. 2, where an individual NCAA baseball was fired into a wood block a total of 120 times and for each consecutive 12 firings an average COR was calculated. The horizontal axis in Fig. 2 represents the number of impacts. The vertical axis represents the average COR of all of the valid impacts for each set of 12 impacts.

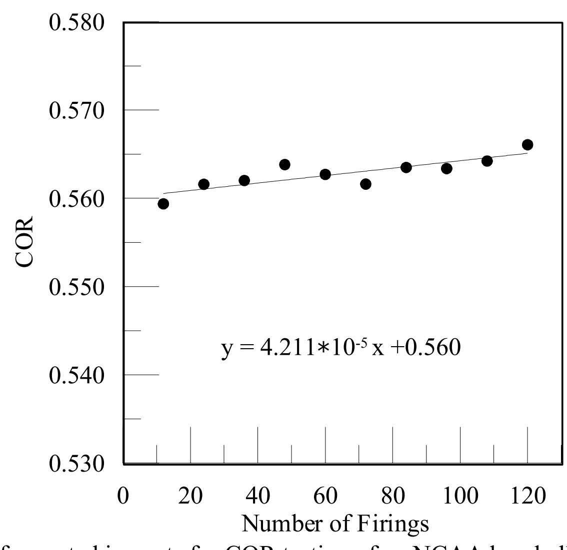


*Fig. 2* Effect of repeated impacts for COR testing of an NCAA baseball

Fig. 2 shows that there is very little, if any, change in COR due to repeated impacts. The results of the current study, though exceeding the ASTM standard maximum of 12 impacts, are assumed to be uncompromised because of the results presented in Fig. 2.

The second method, referred to as the High Speed Method, used for measuring the baseball's COR, had a impact velocity greater than 60 mph. Based on limitations of both the ball firing device, a Jugs Pitching Machine, and the velocity measuring device, a photoelectric speed gate manufactured by Oehler Research Co., a target inbound velocity of 100 mph was selected. An acceptable range of ±1 mph was given to this target velocity so that valid hits would be achievable without accruing a large number of hits on each baseball. Also, to avoid firing the baseballs too many times and potentially causing excessive damage due to the increased impact velocity, the baseball's COR was computed from the average of three impacts. To measure the rebound velocity at this increased velocity, the photogates had to be moved to 20 in from the wood plate–instead of 12 in. The distance between the photogates remained at 12 inches. To allow for recovery, the time between impacts was increased from 30 to 60 s.

***TEMPERATURE CONDITIONING***

Baseballs were conditioned to four different temperatures using three standard household appliances. This study inspected the effect on performance due to relative heating and cooling of a baseball. The weather in different regions of the country and during different parts of the year leads to a variety of playing temperatures. The lab conditions in the Baseball Research Center are maintained at 70°F and 50% relative humidity (RH), these conditions are also the required conditions for performing the standard COR test on baseballs. This combination of temperature and RH will be used as the benchmark for this temperature study.

To study the effect of storing the baseballs in a heated condition, the baseballs were placed in a toaster oven set at 150°F for a period of ~2.5 hours. The associated core temperature was ~120°F. This condition could represent the heat of playing during the summer where the baseball may be left in the direct sunlight for a period of time. The core temperatures were measured using a meat thermometer on a separate baseball that had a very small hole drilled into the center, and the baseball was stored side-by-side with the baseballs preparing to be COR tested.

To study the effect of storing a baseball in a relatively cool condition, the baseballs were placed in a refrigerator. The refrigerator temperature was ~40°F. The baseballs were placed in the refrigerator for a period of ~3.5 hours, by which time the core had reached a temperature of 40°F. This cool-temperature condition represents the low temperatures of a night game in the early spring or late fall. Additionally, a fourth temperature condition was inspected. In either extremely cold conditions or by tampering with the storage of the baseball, a condition where the baseball would be subject to subfreezing conditions was inspected. For these tests, each baseball was placed in a standard freezer for ~3.5 hours. During this conditioning, the core temperature reaches ~25°F.

Each baseball was quickly tested after it was removed from the storage location. Each test took between 3 and 7 minutes to perform. When possible, the baseball was placed back in the oven or in a cold bag between firings to help retain the ball temperature at the condition that was being investigated.

## RESULTS

The results of the tests performed for this study are presented in Figs. 3 and 4. Fig. 3 presents the average COR of the 12 baseballs tested at each of the four temperatures using the Standard Method of COR testing. Fig. 4 presents the average COR of the 6 baseballs tested at each of the same four temperatures using the High Speed Method of COR testing. Both figures show the data within the bound of a statistical certainty of the standard error of the mean as calculated using Eq. 2 (Montgomery, 1998),

$$\sigma_{\overline{X}} = \frac{S}{\sqrt{n}} \tag{2}$$

where $\sigma_{\overline{X}}$ is the estimated standard error of $\overline{X}$ , $S$ is the sample standard deviation and $n$ is the number of samples.

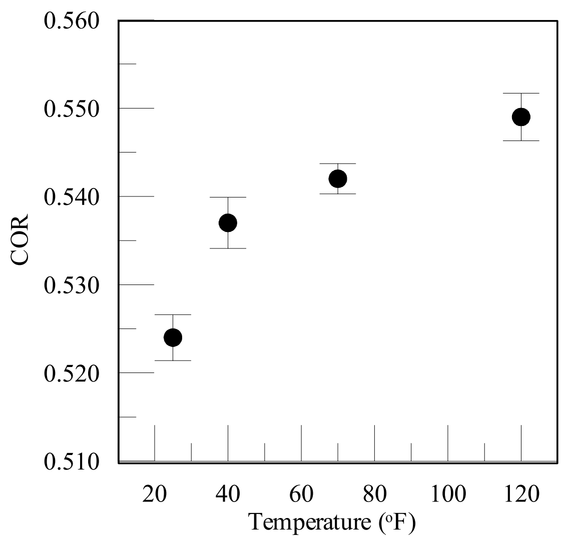


*Fig. 3* Average COR values for 12 baseballs tested at four temperatures using the normal ASTM test speed (60 mph)

The results presented in Fig. 3 show that baseball COR increases with increasing temperature. The error bars show that this trend is statistically significant. The effect of the temperature change from 40°F to 120°F at the standard COR impact velocity of 60 mph is about 2%.

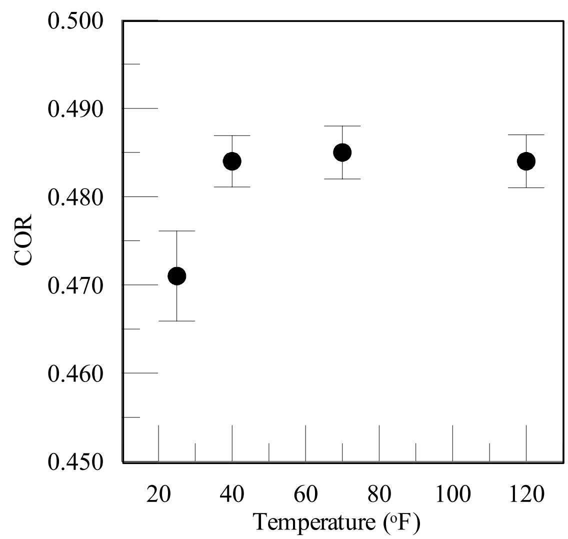


*Fig. 4* Average COR values for 6 baseballs tested at four temperatures using 100-mph impact velocities

The upward trend of the data in Fig. 3 for the three data points at and above 40°F is not observed in Fig. 4. The heating of the baseball from normal temperatures does not appear to change the baseball's COR significantly at the velocities in the High Speed Method, which better represents game-like impact velocities than does the standard 60-mph COR test. The difference in COR for the normally experienced range of temperatures is less than 1%. The effect of subfreezing temperatures on the baseball is more significant. The COR of a very cold baseball was about 3% lower than the same baseball at the benchmark temperature of 70°F. Using the linear relationship between COR and batted-ball distance (Adair, 1994), the data from the High Speed Method can be examined to show that subfreezing of a baseball, COR reduction of 0.014, would result in a loss of about 9 ft on what would have been 400 ft with the same baseball at normal temperatures.

Previous work by Adair identified the relationship between temperature and COR to be linear (Adair, 1994). Both Fig. 3 and 4 show that the trend is more logarithmic, where cooling the baseball has a much more significant change to the COR than does heating it.

## CONCLUSIONS

Understanding what affects the performance of baseballs is as important as understanding what affects the performance of baseball bats when attempting to understand the bat-ball collision. This paper investigated the effect of temperature on baseball COR. The result of testing twelve baseballs at 60-mph velocities and another six at 100-mph velocities at four different temperatures shows a 2% change in COR from the coolest to warmest temperatures that baseballs would experience in normal play–the cooler the baseball the slower the rebound velocity. In the case of exposing the baseball to subfreezing temperatures, the baseball COR dropped by about 3%.

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