Coors Field: A Pitchers Graveyard?

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Batting and pitching statistics for the Colorado Rockies have long been considered inflated by sports writers and fans. Schaffer and Heiny (2006) documented a Coors Field effect on slugging percentage. This research examines the Coors Field effect on pitching statistics, ERA and on-base percentage.

In their 14 years of existence, the Colorado Rockies have not yet distinguished themselves as a "good team". They have only made the playoffs once, as a wildcard team, in the strike shortened season of 1995. It would be easy to blame Rockies pitching, since their statistics are perennially at the bottom of the league. In fact, the Rockies ranked 26 out of 28 teams in opponent batting average in the only season they made the playoffs. The Rockies have always had to make up for their weak pitching with their offensive prowess, aided in part by the elevation of their ballpark, Coors Field. Schaffer and Heiny (2006) demonstrated a significant slugging percentage advantage by playing half of their games in the thin air of Coors Field.

Is the elevation of Coors Field the bane of Rockies and visiting pitchers? The answer of nearly every sportswriter would be an emphatic "*Yes*!" Johnathan Leshansky of athomeplate.com sums up pitching at Coors Field: "Of course pitching at Coors is like trying to defuse a bomb when you have a bad case of the shakes. You might do alright for a while, but the odds are that eventually something is going to blow up in your face." In fact, the general manager for the Rockies, Dan O'Dowd even stated, "I'm not sure even if we had Randy Johnson, Curt Schilling, or those kinds of guys in our rotation. I'm sure they'd be good, but I don't think they'd be as good as they are pitching elsewhere."

According to www.baseball-reference.com, the air pressure in Denver is about 15% lower than at other parks near sea level. Reduced air pressure decreases aerodynamic forces on the baseball by the same amount. Thus, there is less movement on breaking pitches, making them easier to hit, and less drag on balls in flight allowing baseballs to fly further.

In a study performed by Schaffer and Heiny (2006), the effect of elevation on slugging percentage was examined. By performing a repeated measures ANOVA, Schaffer and Heiny concluded that a significant effect of elevation existed on slugging percentage. This study will use the same analyses as Schaffer and Heiny (2006), but examine earned run average and on base percentage.

In order to help bridge the gap between Coors Field being a hitters park versus an average ballpark, the Rockies began putting their baseball's in a humidor. The unorthodox practice began in 2002 and has been ongoing since. The method was so well received that now all 30 MLB teams keep their baseballs in a climate controlled environment. In 2006, the Rockies posted their smallest disparity in earned run average, posting a 4.72 ERA at home and a 4.59 ERA on the road. Part of this receding gap may be due to Rockies pitchers adjusting to the effects of elevation, though many believe that the implementation of the humidor is the main cause.

The effect of high elevation on the flight of the baseball has been studied by Sterling Professor Emeritus of Physics at Yale University and "Physicist to the National League" Robert K. Adair (2002). He wrote, "Since the retarding force on the ball is proportional to the density of the air, the ball will travel farther in parks at a high altitude. A 400-foot drive by Sammy Sosa or Mark McGwire at Shea Stadium, near sea level, on a windless summer day would translate to a 404-foot drive in Atlanta on the Georgia Piedmont at 1,050 feet, the highest park in the majors before 1994. The same home run could be expected to go about 403 feet in Kansas City and 403 feet at the Metrodome in Minneapolis or Wrigley Field in Chicago. These differences are not so great as to modify the game, but Sosa could expect his long drive to travel about 420 feet at mile-high Denver. And if the major leagues are further internationalized someday, say to Mexico City, at 7,800 feet, Sosa's blow could sail nearly 430 feet. Old home run records will be swept away unless the fences are moved out in the high parks."

Adair mentions that moving the fences back is not the only solution. He continues, "Even if the fences are adjusted, the high-altitude stadiums will still be a batter's boon and a pitcher's bane. With fences moved back, there will be acres of outfield for balls to fall into for base hits, and, though the pitcher's fastball will be about six inches quicker in Denver, the curve will bite about 20% less, which is more important.

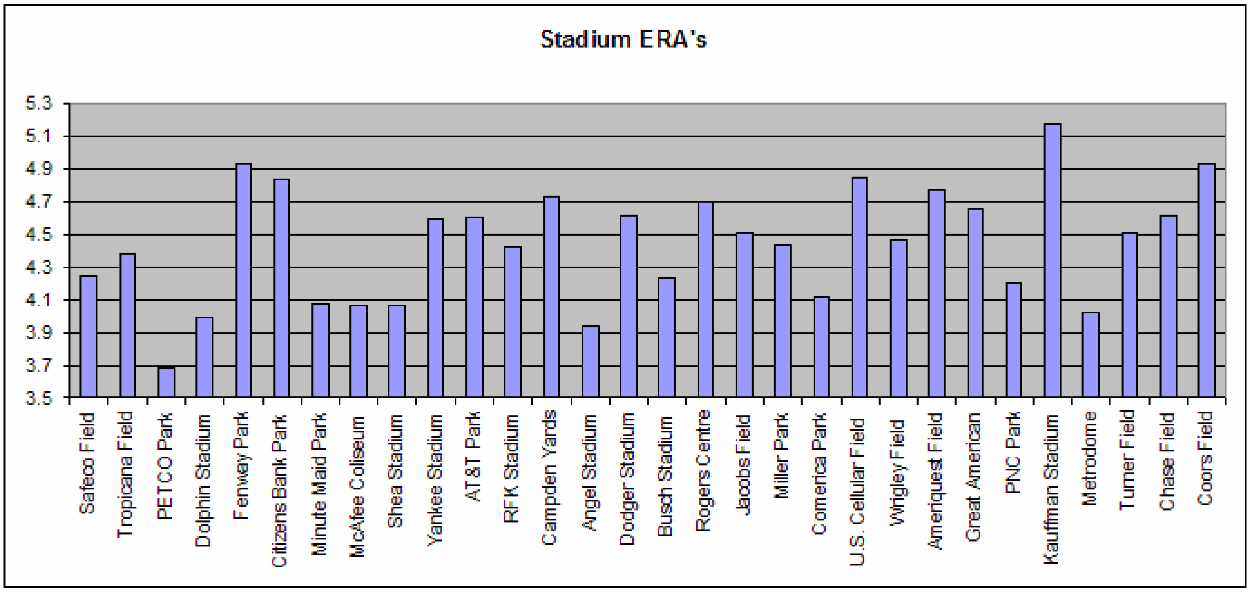

Figure 1. ERA for each Stadium

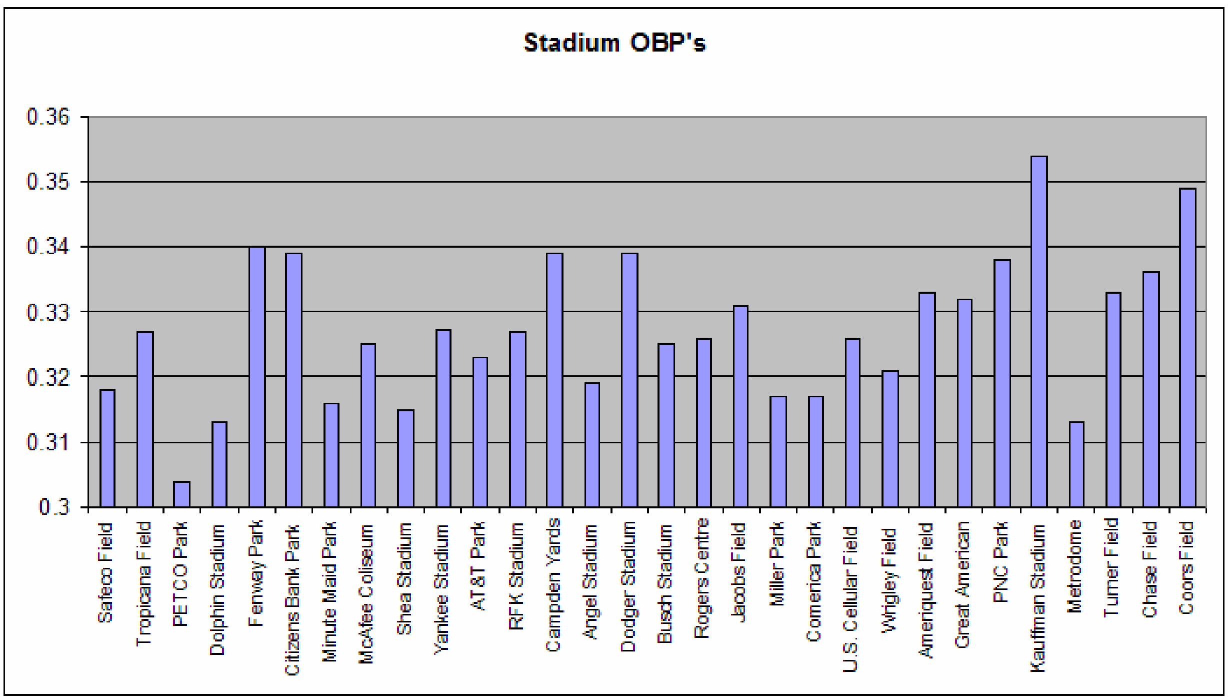

Figure 2. OBP for each stadium.

With less drag, the ball will also get to the outfielders faster in Denver than at Fenway Park in Boston. Players for the Colorado Rockies have noted that in Denver's outfield, 'Fly balls come at you faster and sail farther than you might expect.' Indeed, a hard-hit 'gapper' between the outfielders will reach the 300-foot mark about two-tenths of a second faster in Denver than at sea level, cutting down the pursuit range of an outfielder by five or six feet—not inconsiderable in this game of inches. Even the range of a shortstop covering a line drive or one-hopper will be cut by about a foot in Denver."

When considering the pitching statistics of Rockies starting pitcher Jeff Francis, Adair's theory seems to hold true. In 2006, Francis posted an ERA of 4.30 at home and a 4.05 away. In addition, Francis had a 0.339 on-base percentage against, OBP, at home and a 0.324 on the road. Francis has played his entire MLB career with the Rockies starting in 2004. Thus far, Francis has posted a career ERA of 7.66

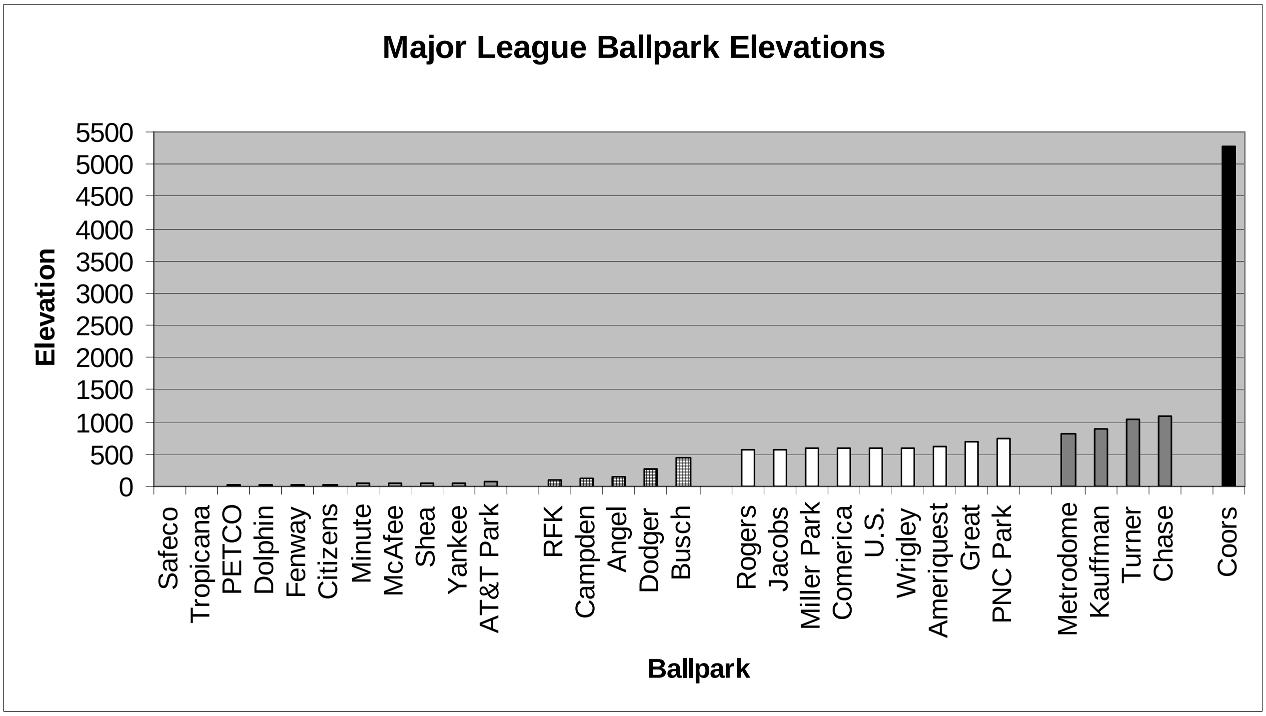

Figure 3. Elevations of major league ballparks.

at Coors Field and a 3.86 ERA on the road. The phenomenon extends beyond just Coors Field. In general, stadiums with high elevation have high pitching statistics. Figures 1 and 2 display 2006 ERA and OBP respectively for each stadium. It should be noted that Coors Field has nearly the highest ERA and OBP when compared with the other stadiums.

Data

Data was taken from sportsnet.ca, a leading Canadian sports company, who obtain their stats from STATS LLC. STATS LLC gathers stats for the Major League Baseball Association. Data was collected such that each pitcher's statistics were tallied for each stadium he pitched at for the 2006 season. The pitching statistics that were collected initially are shown in the appendix 1. Elevations for each ballpark were found using the US Geological survey website, www.usgs.gov, and are shown in Figure 3.

Methods

An ANOVA procedure was used to determine if elevation had a significant effect on pitching statistics. An unbalanced, repeated measures design with nested factors was used. A treatment was considered each combination of ballpark and elevation. The subjects in this experiment were the pitchers. This is considered an unbalanced design because none of the pitchers play at every ballpark. The response variables were ERA and OBP. In this study, ERA and OBP were weighted by innings pitched. The model used is shown below in equation 1:

$$X_{ijk} = \mu + \alpha_i + \beta_{j(i)} + \gamma_k + \varepsilon_{ijk} \; ; \qquad (1)$$

where, X_{ijk} = ERA or OBP of a pitcher; α_i = effect of elevation; $\beta_{j(i)}$ = effect of ballpark; γ_k = effect of player; μ = overall mean ERA; and ε_{ijk} = random error.

The effects for elevation, ballpark and player were treated as fixed effects. The data used in this study were not a random sample of ballparks, elevation or players from a larger population, but rather a collection of pitching statistics from the entire major league for the 2006 season.

In order to test whether elevation had a significant effect on pitchers both ERA and on-base percentage against were used. ERA is one of the oldest and most popular statistics gathered on pitchers. ERA is calculated by equation (2).

$$\text{ERA} = \frac{Number\ of\ \ Earned\ \ Runs * 9}{Number\ of\ \ Innings\ Pitched} \qquad (2)$$

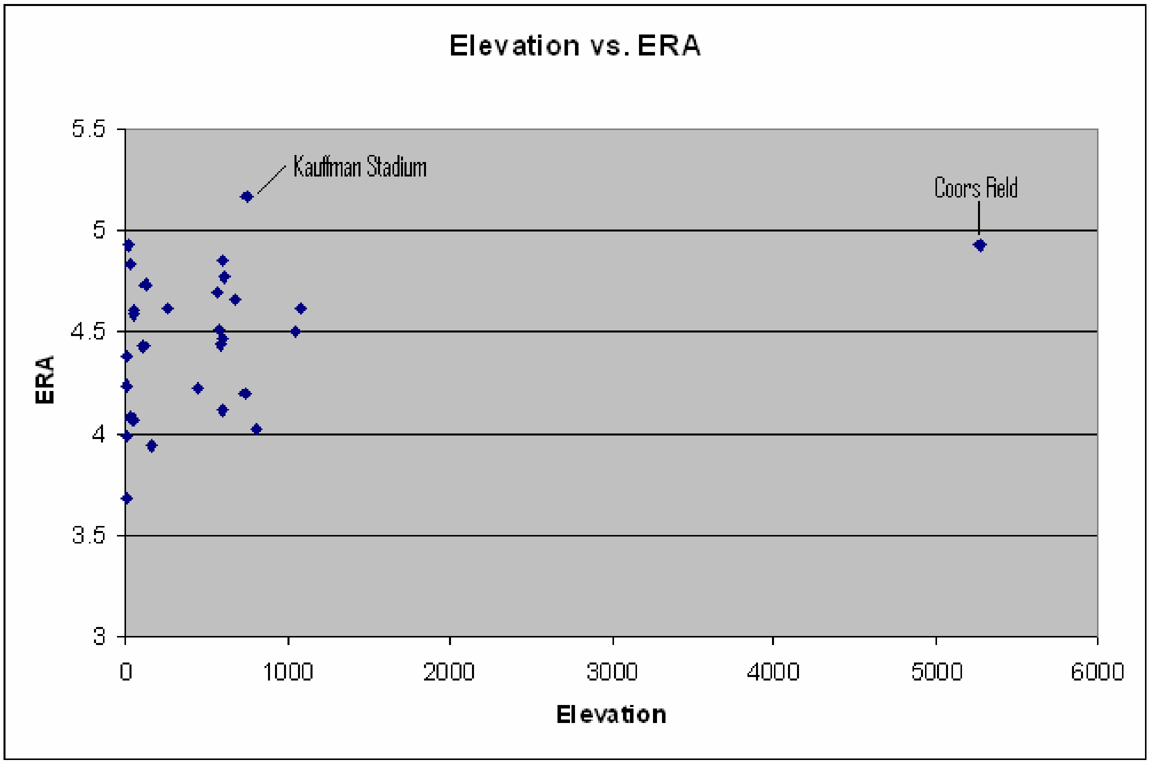

Figure 4. Elevation versus ERA

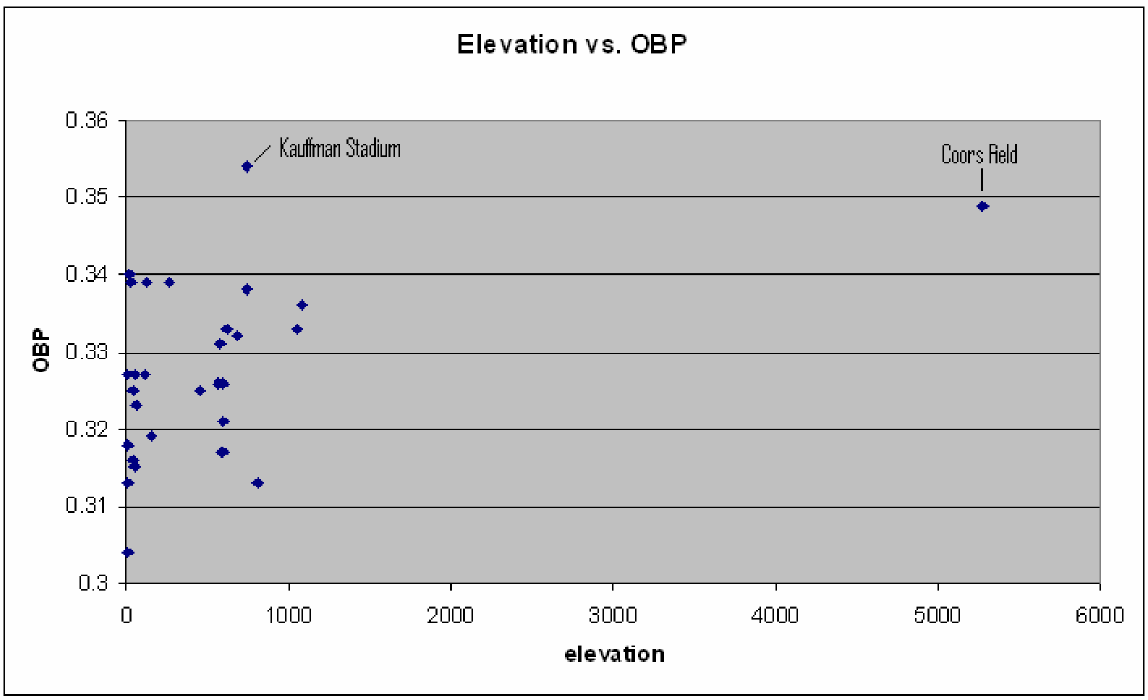

Figure 5. Elevation versus OBP.

Earned runs do not include errors by the catcher or position players, as the pitcher did not control this.

In addition to ERA, OBP was used to capture hits given up by pitchers. While batting average against is a widely used statistic to capture hits given up, it does not account for walks, players hit by a pitch, and sacrifice flies. OBP takes into account these additional statistics and is calculated by equation (3).

$$\text{OBP} = \frac{Hits + Walks + Batters\ Hit\ By\ Pitch + Sacrifice\ Flies}{Number\ of\ Opponent\ At - Bats} \tag{3}$$

Table 1. Levels of Factor Elevation

Level	Elevation Range	Number of Ballparks
1	under 100 ft	11
2	between 100ft and 500ft	5
3	between 500ft and 800ft	9
4	between 800ft and 1,000ft	4
5	over 1.100 ft	1

Using elevation as a numerical variable presents analytical difficulties, as Coors Field is 5,277 feet above sea level and the other 29 ballparks are all below 1,100 feet. Figures 4 and 5 show ERA versus elevation and OBP versus elevation respectively, for each major league stadium. As illustrated in both figures, Coors Field is an obvious outlier with respect to elevation. Due to the leverage point created by Coors Field, it would be detrimental to fit any type of regression model to the data using elevation as a continuous variable. Therefore elevation was categorized into five levels, so that a reasonable number of teams would be distributed into each level of elevation. Coors Field, in Denver, Colorado was categorized into a level of its own for reasons discussed previously. In addition, ballparks with elevations less than 100 feet were considered their own level due to the large amount of ballparks that fit this into that category. The elevation range and number of stadiums in each level is shown in Table 1. The elevation of each major league city is displayed in Figure 3 with a space between each level for the factor elevation.

As seen in Figures 4 and 5, Kauffman Stadium, home to the Kansas City Royals was the only stadium that posted higher ERA and OBP than Coors Field. When considering the characteristics of the Royals, it may be safe to say that factors other than elevation played an important role in Kauffman Stadium's poor statistical showing. With a record of 62 wins and 100 losses, the Royals were one half of a game away from holding the worst record in the major league baseball in 2006. The Royals also posted a league worst 5.68 ERA at home. The overall Kauffman Stadium average for ERA was 5.17 indicating mainly the Royals struggled in the ERA category at Kauffman stadium. This would imply that the elevation may have less to do with Kauffman stadium's high ERA and more to do with the poor pitching on the part of the Royals.

Baseball is different from other team sports in that each ballpark has its own set of unique characteristics. These characteristics can either hinder or help pitchers. The most obvious of these characteristics is that of the length of outfield fences. However other factors may also play an important role. Stadiums such as McAfee Coliseum in Oakland, California and Dodger Stadium in Los Angeles, California have expansive foul territories which aid pitchers and hinder batters. Faster playing surfaces such as Astroturf® and Fieldturf® can make it much easier for ground balls to get through to the outfield for hits. Weather conditions also vary greatly from ballpark to ballpark, with some teams playing indoors in a climate controlled environment, such as Minnesota Twins, and while others like the White Sox in Chicago battle the wind. Rather than trying to account for all the stadium factors separately, an overall ballpark factor was used. The overall ballpark factor is nested within the factor elevation.

It is also of interest to note that the American League has consistently higher run production over the National League, because the rules dictate that teams in the American League may have a designated hitter to hit in place of their pitcher, while teams in the National League do not have this luxury. A simple t-test comparing the means of both ERA and OBP for each league showed there was not a significant difference. Thus, league was not included as a factor in the model.

The opposing team may be an important factor in the model shown in equation 1, as certain teams tend to have better offensive production than others. Unfortunately, those statistics were not available at the time of this study. Therefore, opposing team offense was not considered as a factor.

Results

Results were found using PROC GLM in SAS. An ANOVA table for ERA and OBP was generated for the model shown in equation 1. The model using ERA as a dependent variable is shown in Table 2 while the model using OBP is shown in Table 3.

The R^2's for the ERA and OBP models were 0.14 and 0.18 respectively, which seems to indicate that both models do not account for a large portion of variation for their respective dependent variables. However, low R^2 values have been common in previous baseball studies. In the analysis performed by Schaffer and Heiny (2006), they stated, "Additional independent variables could be added, but most likely the randomness of baseball never can be accounted for completely. Players go through hot and cold streaks for reasons they do not even understand." The "hot and cold streaks" that Schaffer and Heiny

(2006) refer to are independent of ballpark and elevation, but still contribute variability to the study. Previous studies have made similar conclusions regarding the randomness of baseball. Hofacker (1998) analyzed major league baseball data for the 1982 season. The study attempted to measure a baseball team's offensive ability independent of opponent and ballpark. Hofacker used runs scored as a dependent variable, and opponent, park, league and home versus away as independent variables. The R^2 for this study was 0.267. Hofacker defended his low R^2 by stating, "While it is true that researchers in some fields might scoff at such a low R^2, perhaps the better way to think about the current result is that it offers insight into just how stochastic baseball must be. Such considerations necessarily imply that the analysis presented be considered exploratory." The purpose of this study is not to predict ERA or OBP for a pitcher, but rather to determine if elevation is a significant effect on pitching.

Table 2. ANOVA Table for ERA

Source	*df*	Sums of Squares	Mean Square	*F*-value	*p*-value
Model	651	79,393.12	121.96	1.39	<.0001
Error	5,625	494,360.76	87.89		
Corrected Total	6,276	573,753.88			

Table 3. ANOVA Table for OBP

Source	*df*	Sums of Squares	Mean Square	*F*-value	*p*-value
Model	651	58.77	.09	1.95	<.0001
Error	5,625	260.59	.05		
Corrected Total	6,276	319.36			

Table 4. Repeated Measures ANOVA Table for ERA

Source	*df*	Sums of Squares	Mean Square	*F*-value	*p*-value
Elevation	4	1027.60	256.90	2.92	0.0199
Park(Elevation)	25	2971.59	118.86	1.35	0.1127
Player	622	74,424.28	119.65	1.36	<.0001
Error	5,625	494,360.76	87.89		

Table 4. Repeated Measures ANOVA Table for OBP

Source	*df*	Sums of Squares	Mean Square	*F*-value	*p*-value
Elevation	4	0.94	0.23	5.09	0.0004
Park(Elevation)	25	2.38	0.09	2.05	0.0015
Player	622	53.81	0.09	1.87	<.0001
Error	5,625	260.59	0.05		

Tables 4 and 5 list each factor with its degrees of freedom, Type III sums of squares, mean squares, *F*-statistics and *p*-values for ERA and OBP, respectively. Elevation has a statistically significant contribution to both ERA and OBP. The *p*-value for ERA was 0.0199 and 0.0004 for OBP. The compound symmetry assumption for this study was violated due to the hot and cold streaks that pitchers experience during the season. Pitches thrown in a game are likely to be highly correlated, while pitches thrown in a different game will be less correlated. Regarding the compound symmetry assumption Neter et al. (1996) stated, "In repeated measures studies, the compound symmetry assumption will be violated, for instance, if repeated responses over time are more highly correlated for observations closer together than for observations further apart in time." Neter et al. (1996, *p*. 1170) suggested using a more conservative critical value because the test becomes more liberal when the compound symmetry assumption has been violated. Even with this more conservative critical value, $F(0.95;\ 1,\ 622) = 3.84$, elevation still has a statistically significant effect on OBP. However, using the more conservative critical value for the ERA model shows elevation is no longer statistically significant effect.

Despite ERA no longer being significant, using the conservative degrees of freedom suggested by Neter et al., a post hoc test was still performed in order see if differences still existed between elevations assuming the compound symmetry assumption had not been violated. A post hoc test was also performed on the OBP model. Glass and Hopkins (1996) suggest using Student Newman-Keuls (SNK) due to its power and high degree of protection for the entire [omibus] null hypothesis. The results from the SNK tests for ERA and OBP are shown in Tables 6 and 7 respectively. Groups with different SNK groupings (A versus B) are statistically different from each other. N represents the number of players who pitched at that particular elevation level. In addition, the means for ERA and OBP are shown for each level of Elevation in Tables 6 and 7.

Table 6 shows that Coors Field, in elevation 5, is statistically different from ballparks located in the two lowest elevations, 1 and 2. It should be noted that as elevation increases, intuitively ERA increases
too. By looking at the mean ERA per elevation, it would appear there are three relative groups. The two lowest elevations, 1 and 2, have a mean ERA near 4.35, while ERA for elevations 3 and 4 are near 4.55, and the highest level, Coors Field, is 4.93. The mean ERA for the Coors Field elevation is about 8.4% higher than the "middle elevations" and 13.3% higher that the "low elevations."

Table 6. ERA by Elevation.

SNK Grouping		Mean	*N*	Elevation
A		4.9330	216	5
B	A	4.5800	828	4
B	A	4.5296	1870	3
B		4.3941	1037	2
B		4.3043	2326	1

Table 6. ERA by Elevation.

SNK Grouping	Mean	*N*	Elevation
A	0.342	216	5
B	0.329	828	4
B	0.325	1870	3
B	0.323	1037	2
B	0.319	2326	1

The post hoc test for OBP showed that there is a statistically significant difference between the elevation of Coors Field and the other four levels of elevation. The OBP means for each level of elevation exhibit the same trait as ERA; as elevation level increases, so does OBP. Contrary to the findings of ERA, the post hoc test for OBP did not show three distinct groups, but rather two distinct groups, Coors Field versus the other four levels. The mean OBP for Coors Field is 4% higher than elevation 4, and 7.2% higher than elevation 1.

It should be noted that due to Coors Field being an numerical outlier in elevation, and the only ballpark in elevation category 5, the ballpark effect and elevation effect are confounded. However, Coors Field is one of the largest ballparks in the Major Leagues. In fact, Coors Field has the second longest left field dimension, and third longest center and right field dimensions in Major League Baseball. Despite these large dimensions, the z-scores for Coors Field within each set of 30 left field, right field and center field dimensions were 1.70, 1.32 and 1.80 respectively; indicating Coors Field is not an outlier with respect to ballpark dimensions. Additionally, Coors Field has a relatively small foul territory, but is still similar to most other ballparks. The abnormally large foul territories of Dodger Stadium and Network Coliseum are the exception rather than the rule.

It would appear that Denver's outlier status with regards to elevation is the only factor that makes Coors Field significantly different from the other ballparks. It is therefore reasonable to conclude the high elevation is the primary cause for the high ERA and OBP exhibited at Coors Field.

Conclusions

The model used in this paper has demonstrated that elevation significantly impacts OBP, independent of ballpark and player. The model also showed that elevation marginally impacts ERA, but is consistent with the theory that ERA increases as the elevation increases. At Coors Field, ERA is approximately 8.4% higher than the middle elevations between 500 and 1,100 feet, and 13.3% higher than the low elevations less than 500 feet. Differences in OBP showed Coors Field in "a league of its own", with the other four elevations grouping close together at lower values.

Given that young Rockies prospect Jeff Francis has played his entire career at the with the Rockies, it may interest a team owner, manager, sports writer or fan to know how well he might do if he were traded to different team. If Francis was traded to a middle elevation team his home ERA of 4.30 in 2006 would be adjusted down to 3.94 and OBP would have to be adjusted from 0.339 to 0.323. This would give Francis an overall ERA of about 4.00 and an OBP of about 0.324 if he were to be traded to a middle elevation team. If he were to be traded to a low elevation team, his expected ERA and OBP would drop even further. His home ERA would now drop to 3.73, and his OBP would drop to 0.317. This would bring his overall ERA to a respectable 3.89 and his OBP to 0.321.

This study determined that the effect of elevation and ballpark are confounded in Denver. However an examination of the ERA and OBP effects of each ballpark versus elevation level and the dimensions of Coors Field with respect to the other ballparks rule out the ballpark effect explaining the high OBP and ERA experienced at Coors Field. In fact, elevation appears to be the only viable explanation.

The results seem to indicate that there may be other variables and factors (weather, opposing team batting average, etc) that may influence ERA and OBP. While additional independent variables may be added to the model to account for more error, most likely the model would only be improved marginally. The randomness of baseball can probably never be fully accounted for. Players go through hot and cold streaks throughout the season that even they cannot explain. Certainly, even some players may have an off season, or some may be partial to pitching at certain times during the day.

Future studies may want to examine the effect of the humidor used by the Rockies, and other teams, to see if it has an effect on the game. It may also be interesting to follow several Rockies players over the course of several years, in a longitudinal study, to see if their pitching or hitting statistics change over the course of their transition from the Rockies to a different team and vice-versa. Variables such as temperature, left versus right handed, and years in the league could also be on importance variables in future studies.

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Appendix 1

Statistic	**Definition**
G	Games Played
GS	Games Started
ERA	Earned Run Average
W	Wins
L	Losses
SV	Saves
IP	Innings Pitched
H	Hits
R	Runs
ER	Earned Runs
BB	Bases on Balls (Walks)
CG	Complete Games
SVO	Save Opportunities
HR	Home Runs
2B	Doubles Given up
3B	Triples Given up
OPAVG	Opponent Batting Average
OBP	On-Base Percentage Against
SLG	Slugging Percentage