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Performing at the Highest Level: Does Stadium Elevation Play a Role in Home Field Advantage in FBS College Football?

David Zinn [1] | **David Fowler** [2]

1. Assistant Professor of Sport Management, Lander University, Greenwood, South Carolina, U.S.A.
Email: dzinn@lander.edu
2. Corresponding author, Assistant Professor of Management, Louisiana State University Shreveport, Shreveport, Louisiana, U.S.A.
Email: david.fowler@lsus.edu

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ABSTRACT

This study investigates what effect stadium elevation has on the win-loss performance of home teams in major college football. Despite extensive research on factors that influence home-field advantage in sports, the potential impact of altitude on the performance of college football teams has not been thoroughly explored. Therefore, the purpose of this study is to compare the records of institutions playing home games at the highest elevation stadiums with national averages. In contrast to its effect on sports like international soccer or running, results indicate that teams playing in stadiums at higher elevations have no significant difference in win-loss percentage than the national average as findings suggest that altitude does not play a significant role in the performance of FBS teams. Unlike soccer teams playing in high-altitude cities or runners training in the mountains prior to racing at lower levels, this study concludes that playing in stadiums located at higher elevations does not significantly impact win-loss percentage of college football teams. This study contributes to the understanding of the factors that influence home-field advantage in college football and the limited impact of altitude on college football.

Introduction

An article describing the perceived home field advantage enjoyed by the University of Utah's football team stated that "sitting at 4,600 feet above sea level, it goes without saying that Rice-Eccles Stadium's elevation certainly plays into Utah's favor" (Mullin, 2021). Mullin further claimed that visiting teams tend to become fatigued in the second half when the effects of the higher elevation become more apparent. This assertion poses the question as to whether a stadium's elevation does indeed have a positive impact on a college football team's home field advantage.

Research notes the existence of a physiological effect of altitude on the human body as well as on individual and team performance in sports and activities such as running (Maxwell, et. al, 2019),

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cycling (Gonzalez-Parra et al., 2013), and mountain climbing (Khodaee et al., 2016). However, apart from international soccer, little research has been conducted to determine if altitude provides a unique home-field advantage in team sports, specifically at the intercollegiate level. Thus, the purpose of this study is to determine if a stadium's elevation offers any benefit in college football (Football Bowl Subdivision) to teams that play their home contests in stadiums at higher altitudes.

While numerous studies have researched the effect of altitude on sport performance, most have focused on individual sports, particularly running, as the effect of altitude is a principal factor in the "train high/race low" philosophy of training preferred by many athletes and coaches (Maxwell et al., 2019). Far less research, however, has been conducted on the effects of altitude in team sports with most of these focusing on European Fédération Internationale de Football Association (FIFA)/World Cup Soccer teams traveling to higher altitudes for matches in South America, specifically high-altitude cities/stadiums in Columbia, Bolivia, and Ecuador.

One such study on the effects of altitude indicated that soccer players who were long-term residents of altitudes near sea level were under far greater stress at 3,600 meters (approximately 11,800 feet) when compared with players whose primary residence was at that altitude. Further, players from cities located near sea level who competed in high-altitude stadiums experienced a greater decrement in maximum aerobic power, higher blood lactate levels, and lower blood saturation when compared with those athletes accustomed to playing at these heights (Gore et al., 2009). Additionally, studies show that participating in any physical activity at a higher altitude with a drop in air pressure, combined with potential cold and dehydration, can lead to nausea, dizziness, fatigue, and headaches as well as more serious medical conditions such as pulmonary or cerebral edema (McSharry, 2007).

Concerning home-field advantage, studies have revealed that this phenomenon tends to exist throughout competitive sport. Historically, studies have shown that by playing games in home arenas, the home team tends to "win over fifty percent of games played under a balanced home and away schedule," a trend that appears to be universal across sports (Courneya & Carron, 1992). Lending credence to this trend is the fact that home teams who are relocated to a less-familiar venue tend to win at lower rates while experiencing an overall reduced home-field advantage (Pollard, 2002). Further, another study of home field advantage across a number of sports suggested that home teams win approximately sixty percent of athletic contests and that there is little difference in this percentage when comparing individual and team sports or professional versus intercollegiate contests (Jamieson, 2010). Additionally, a historical compilation of games played in Major League Baseball (since 1876), the National Hockey League (since 1917), the National Football League (since 1933), and the National Basketball Association (since 1946) reveals that the average winning percentage of visiting teams per season, with very few exceptions, fails to reach the fifty percent mark nearly every time (Pollard & Pollard, 2005).

The reasons for home field advantage in sport vary according to several studies. According to Wang et al. (2011), visiting teams face several challenges including fatigue from travel, opposing crowd size and noise, disruption to familiar routines and habits, and unintentional favoritism toward home teams by officials and referees. Comparatively, other researchers have determined that the higher probability of victory for the home team derives from venue familiarity and crowd contribution (Watkins, 2013). In addition to these factors, other explanations considered have included territoriality, rule changes, differing game tactics, and psychological barriers (Pollard & Gomez, 2009). One study of college football suggests that a six-point advantage exists for home teams overall and a seven-point advantage is enjoyed by higher strength opponents when playing at home against weaker opponents (Fullagar et al., 2019). Other data suggests one of the biggest impacts in home-field advantage in the National Football League (NFL) is that of weather acclimatization – home teams tend to outperform visiting teams to a significantly higher degree when they have a greater edge in cold acclimatization, an advantage that increases as the temperature difference increases (Coleman, 2017).

Studies on the combined concepts of team sport performance and home-field advantage regarding altitude have been limited primarily to the sport of soccer and mostly in high-altitude stadiums in South America. In 2007, FIFA, citing an "unfair advantage," proclaimed that no World Cup Qualifying matches could be played in stadiums above 2,500 meters (approximately 8,200 feet), effectively eliminating hosting opportunities in Bogota, Columbia, La Paz, Bolivia, and Quito,

Ecuador. Campaigns against this ban resulted in the raising of the maximum altitude limit to 3,000 meters, making the ban binding only for Stadium Hernando Siles in La Paz though an exception was later made for this stadium (Chumacero, 2009).

Further studies demonstrated that altitude has a direct impact on performance. Data suggests that soccer players tend to show a significant decrease in peak oxygen consumption and physical activity levels at high altitudes (Brutsaert, 2000). Additionally, one study indicated that when two teams from the same altitude played, the probability of the home team winning was 0.50, but the home team win probability increased to 0.57 if a theoretical opponent whose home venue was at 3,600 meters was hosting a team from sea level. Moreover, the probability of a home victory rose to an even greater extent, to 0.73, if a team playing at sea-level hosted a team from a high-altitude venue (Gore, et. al, 2008). Furthermore, soccer teams whose home venue resides in high elevation cities in South America tend to score more goals and concede fewer goals with increasing altitude differences from their opponents (McSharry, 2007). Finally, professional baseball statistics have been affected by altitude changes – one study of performance in Short-Season A and Rookie Leagues demonstrated that the number of home runs hit, runs scored, and on-based percentage strongly correlated with rises in elevation (Richardson, 2014).

Methodology

For purposes of this study, the win-loss records for all NCAA Division I football teams competing at the FBS level as of the 2000 season were recorded from 2000 to 2021. These records were broken down into three categories: (a) overall win-loss record, (b) win-loss record at the home venue, and (c) win-loss record at road or neutral sites. For occasional occurrences where two teams shared a home venue, such as the University of California-Los Angeles (UCLA) and the University of Southern California (USC) at the Rose Bowl, both teams were classified as home teams in games in which they played each other. Conversely, despite one team being designated as the home team and one as the visitors in neutral site games, such as Army and Navy playing in Philadelphia, PA or Baltimore, MD, both teams were designated as road teams if both were playing away from their home venue. Additionally, any team playing in their traditional home stadium, such as Boise State playing in the Idaho Potato Bowl, for example, even if the game was technically designated as a neutral site, was classified as a home team.

Records were obtained from games played since 2000 and each team's overall win percentage, home win percentage, road win percentage, and the difference between home and road win percentage were calculated. From this data, averages were calculated to determine national norms in each category. A Pearson calculation and linear regression were deployed to analyze the possible correlation between stadium altitude and home-win percentage considering all current FBS venues. Finally, data collected from the teams playing in the highest fifteen stadiums, ranging from 7,215 feet (Wyoming) to 2,430 feet (Arizona), and the highest five stadiums ranging from 7,215 feet to 5,003 feet (Colorado State), were analyzed separately so these measurements could be compared against one another and the national averages previously determined.

Of note, the 2020 season that was impacted by the coronavirus pandemic was excluded from this study. Due to a variety of factors caused by COVID-19, many teams did not complete a full schedule and many games were played in front of limited, or in some cases, no fans. Research conducted on the 2020 season demonstrated that home field advantage was impacted due to the smaller, or nonexistent, crowd sizes (Cross & Uhrig, 2022; Hill & Van Yperen, 2021; Krieger & Davis, 2022; Losak & Sabel, 2021) and, thus, this season was not included in this review.

A sample of the home winning percentage of the highest fifteen college football stadiums based on elevation is found in Table 1.

Table 1. Home winning percentage of highest 15 FBS stadiums (by elevation)

Stadium Elevation	Team	Home Stadium Elevation (feet above sea level)	Home Win %	Overall Win %
1	Wyoming	7215	53.175	41.016
2	Air Force	6621	68.992	57.414
3	Colorado	5360	52.419	40.613
4	New Mexico	5100	45.736	38.372
5	Colorado State	5003	55.833	45.977
6	Utah State	4710	60.345	45.174
7	Utah	4657	75.000	67.293
8	Brigham Young (BYU)	4642	73.228	62.687
9	Nevada	4610	65.6000	51.136
10	New Mexico State	3980	39.316	26.772
11	Texas-El Paso	3910	49.180	34.902
12	Texas Tech	3212	66.923	57.143
13	Boise State	2700	91.111	82.482
14	Washington State	2510	54.331	48.263
15	Arizona	2430	52.555	43.969

Results

In reviewing the performance of FBS college football results since the 2000 season, several conclusions can be drawn from the data. First, in evaluating the 114 teams that have been playing FBS Football since the 2000 season, there is a combined overall win percentage of .528, ranging from the highest of .836 (Ohio State) to the lowest of .267 (New Mexico State). Of the teams who met this study's criterion, sixty-six (58%) posted an overall winning percentage of .500 or better while forty-eight teams (42%) posted losing records over that time.

Further analysis of the winning percentage of these teams indicated that home-field advantage was a positive factor in how teams performed as 100% of the teams in this study (n=114) won more often at their home venue than at a road or neutral site. The average home winning percentage since 2000 was calculated to be .635, ranging from a high of .923 (Oklahoma) to a low of .368 (Duke). Moreover, ninety-seven teams (85.1%) posted a winning record at home during that period compared to only seventeen (14.9%) who did not. Comparatively, teams playing away from home posted a combined winning percentage of only .425, ranging from a high of .764 (Ohio State) to a low of .161 (New Mexico State). Additionally, only thirty teams (26.3%) achieved winning records on the road compared to the eighty-four teams (73.6%) who posted overall losing records away from home.

Not only did teams win more often at home than on the road, but the difference was also generally by a large percentage. All 114 teams posted a negative difference between home and road/neutral winning percentage with the average difference being (-.20637). In other words, on average, the team that won sixty percent of their games at home could be expected to win approximately forty percent of the time away from their home venue. This result ranged from a low difference of -.0667 (Northwestern) to a high difference of -.381 (Arkansas State).

In analyzing teams whose stadiums are among the highest fifteen in the nation (excluding Appalachian State which was not playing FBS football as of 2000), the difference in the performance of these teams and the national averages was relatively slight. The overall winning percentage of these fifteen teams was calculated to be a .495, for a difference of (-.033) from the national average (.528). Likewise, the home winning percentage of these teams was .603 (a difference of -.029 from the national average), ranging from a high of .824 (Boise State) to a low of .268 (New Mexico State). Thus, these data points indicate that teams playing home games in the highest fifteen stadiums in the nation have (a) won less overall than the national average, (b) have won less at home than the overall

average, (c) have won on the road less than average, and (d) had a higher difference from the average overall difference, though all by small margins.

Further assessment of this data reinforces that teams hosting games at higher altitudes have performed below national averages. Of the teams playing home games in the highest fifteen stadiums, only six (40%) have won more than half of their games overall and only five (Boise State, Utah, BYU, Air Force, and Texas Tech) have win-loss records higher than the national average over the last twenty seasons. Sixty percent of these schools have a lower home win percentage than the average national home win percentage and three teams (Texas El-Paso, New Mexico, and New Mexico State) are among the seventeen schools nationwide that have lost more games at home than they have won.

When limiting the data to the highest five stadiums, or those whose elevation is 5,003 feet or higher (Wyoming, Air Force, Colorado, New Mexico, and Colorado State), similar yet more pronounced, information appears. Teams from these stadiums win less often than the national average by a (-.0816) difference, ranging from .574 (Air Force) to .384 (New Mexico). Additionally, these five teams win at home less often than the national average by a (-.0793) difference, ranging again from .0534 (Air Force) to -.174 (New Mexico) and they win less often on the road, ranging from .463 (Air Force) to .232 (Wyoming). Of these five teams, only one (Air Force) has won more than the national average in overall win percentage, home win percentage, and road win percentage and all five have lost on the road more often than they have won.

Pearson calculation and simple linear regression analysis provide validation for the provided manual data analysis. The linear regression results, $\hat{y} = -0.00072X + 63.93711$, reveal a negative correlation, albeit weak, between stadium altitude and home-win percentage. The Pearson calculation also provides the same validation $r(114) = -.08$, $R^2 = .005$, and $p = .374$. While technically a negative correlation, the results are not statistically significant at $p < .05$.

Ultimately, these results show that there is no statistical significance in the correlation between stadium altitude and home-win percentage, and this is illustrated in Table 2.

Table 2. Statistical Analysis

Statistical Analysis	Result
Linear Regression Equation	$\hat{y} = -0.00072X + 63.93711$
Correlation Coefficient (Pearson)	$r(114) = -0.08$
Coefficient of Determination (R^2)	$R^2 = 0.005$
Significance Level (p)	$p = 0.374$ (not statistically significant)

A graphical representation including scatter plot information based on linear regression is found in Figure 1.

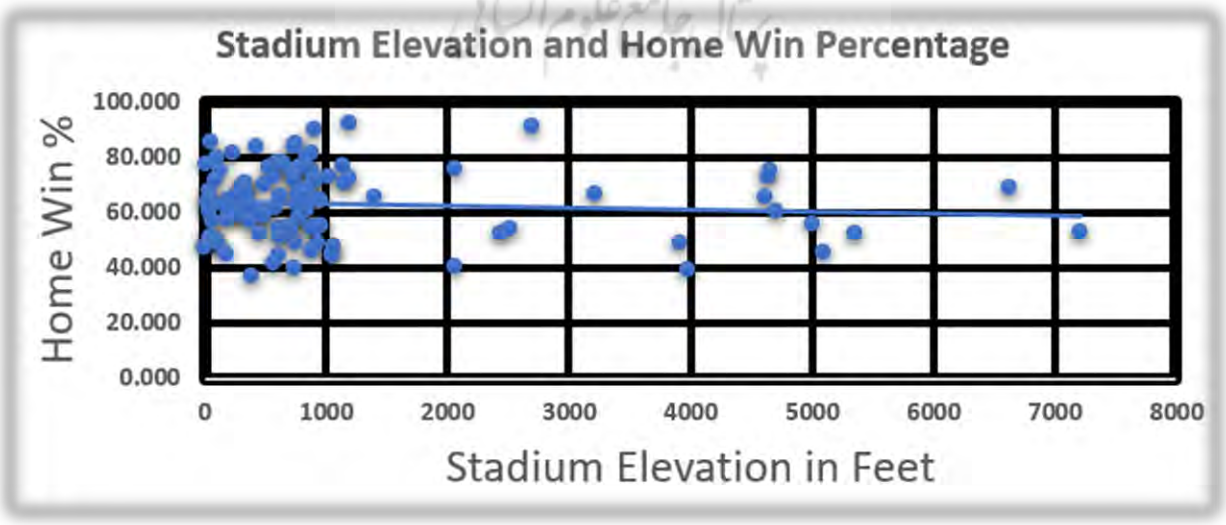

Figure 1. Stadium Elevation and Home Win Percentage

Discussion and Conclusion

While using game outcomes such as wins and losses creates noisy and somewhat random variables that are subject to error and are affected by multiple factors such as team quality, weather, coaching changes, player injuries, etc., from the evidence collected over these seasons, there appears to be no competitive advantage in terms of overall win-loss records for teams playing at home in higher elevations. Cumulative results among these teams were varied as evidenced by both the second-best overall win percentage (.843 by Boise State) and the worst overall win percentage (.268 by New Mexico State) hosting home games in one of the highest fifteen stadiums in the nation and, overall, the FBS teams that play among the highest stadiums in the nation have performed worse both at home and on the road or in neutral site venues than the national averages. Thus, from the data collected over the past twenty seasons, there seems to be little concern for teams from lower elevations being at a competitive disadvantage when traveling to the higher stadiums in college football. This evidence would suggest that despite the effects high altitude has on the human body, avoiding the scheduling of these games or making substantial changes to routines in training, travel arrangements, acclimatization attempts, etc., is not necessary for teams traveling to higher elevations to play college football, even to those five stadiums higher than 5,000 feet.

Of importance to note, however, in FBS college football, the differences in altitude change are not as extreme as in other sports, likely lessening the impact of elevation on performance. Unlike soccer teams competing in South America and traveling from sea level to elevations higher than 9,000 feet, only nine college football stadiums reside higher than 4,000 feet with the highest at 7,215 feet. With nearly 100 college football stadiums residing at elevations of 2,000 or fewer feet in altitude, the impact of the elevation change is likely to be far less in most of these locations.

Related to the impact of altitude may be the impact of weather on team performance. As noted in the literature review, weather acclimatization has a large impact on games in the NFL as home teams tend to perform better when the visiting team must adapt to cold weather (Coleman, 2017). As elevation increases, the likely difference in weather and temperature could play a role in team performance as well.

Also potentially affecting these results may be the quality of the teams playing in these venues. Of the teams playing in the highest fifteen stadiums, only five (Colorado, Utah, Texas Tech, Washington State, and Arizona) are current members of an FBS "Power Five" conference. Outside of Boise State, which ranks second in overall win percentage at .843, the next best-performing team from a higher elevation stadium in terms of overall win percentage is Utah at .673, which is 16th best of the 114 teams reviewed; Washington State and Arizona both have overall losing records during this period. Certainly, less competitive teams are going to produce weaker win-loss records regardless of the location where games are played. Therefore, a further examination of the quality of teams that have played in these stadiums may be warranted.

An additional potential area for future research on this topic involves exploring non-conference opponents playing games on the campus of members of the Mountain West Conference. Seven of the highest fifteen stadiums are at institutions that are members of the Mountain West and, therefore, play each other on a regular and reoccurring basis. Hence, the effects of altitude on these visiting teams playing within this conference may be less than those who are traveling from closer to sea level as they are already playing at higher elevations. Put another way, the effect of altitude on the football team from Nevada (4,610 feet) during a visit to play a conference game at Colorado State (5,003 feet) may be less than the effects of, for example, Miami (11 feet) or Houston (39 feet) traveling from sea level to play a non-conference contest at Brigham Young (4,642 feet) or Air Force (6,621 feet). Thus, a focus solely on teams from outside the Mountain West or higher elevation stadiums in general who play a road game against one of these opponents may help to determine if this impact may be higher than discovered in this study.

While findings of home field advantages due to elevation were not significant, this review may prove beneficial to athletic administrators and team coaches in the decision-making process of scheduling future contests. As results from the past twenty seasons suggest that altitude does not appear to be a causation factor in terms of wins and losses, considerations of the potential impact of playing at altitude such as adjusting travel, training, schedules, and/or acclimatization for teams from

lower altitudes preparing to play in locations at a higher elevation may not be particularly concerning. Coaches/athletic administrators considering playing games at higher elevation or conferences expanding to include institutions with a higher-altitude stadium may also examine this data and ultimately conclude that concerns and/or beliefs about a competitive advantage for the home team based on this factor are likely to have minimal, if any, impact on game outcomes.

While this study contributes valuable insights into the relationship between stadium elevation and home-field advantage in FBS college football, there are several limitations to be acknowledged. Firstly, the analysis relies on historical win-loss records, which, while providing a substantial dataset, may not capture the nuanced variables influencing team performance. Factors such as changes in coaching staff, player injuries, and evolving team strategies were not explicitly considered in this research, potentially impacting the overall interpretation of results.

Additionally, the focus on elevation as a singular factor influencing home-field advantage oversimplifies the complex nature of athletic competition. Other environmental factors, such as weather conditions and temperature variations at different altitudes, could potentially contribute to the observed outcomes. The study also does not delve into the psychological and sociological aspects that may influence teams playing at higher elevations, which could be avenues for future research.

Moreover, the exclusion of the 2020 season due to the COVID-19 pandemic introduces a temporal limitation, as the unique circumstances of that season might have influenced home-field advantage differently. Future research could explore the long-term implications of unforeseen events on the dynamics of home-field advantage.

Finally, the study primarily focuses on FBS college football, and the generalizability of findings to other sports or competitive levels remains uncertain. Each sport may have distinct characteristics and responses to environmental factors, necessitating caution when extrapolating these results beyond the scope of college football.

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