The Effects of Altitude on Soccer Match Outcomes

Tyler Williams
Massachusetts Institute of Technology
Cambridge, MA, United States, 02139
Email: tkwillia@mit.edu

Abstract

Leave 2 lines between the authors' affiliation and the start of the abstract.

Soccer teams regularly compete at altitudes above 2,000 meters (6,562 feet) with World Cup qualification or other honors on the line. Media, fans, and players often question the fairness of playing at high altitudes, and FIFA temporarily banned international matches above 2,500 meters (8,200 feet) in 2007. Researchers agree that traveling to higher *or lower* altitude can harm athletic performance, but the effects on professional athletes may be too small to influence match outcomes. Additionally, many teams try to limit altitude effects by allowing players extra time to acclimatize before a match. To identify the causal impact of altitude change, I compare South American international match outcomes between the same teams but played at different altitudes within the same country. This approach controls for influences such as differences in travel distance for high and low altitude countries. I find that traveling to lower altitude does not affect performance but traveling to higher altitude has negative effects. In particular, away teams perform poorly in Quito, Ecuador (2,800 meters), and La Paz, Bolivia (3,600 meters). However, away teams do relatively well in Bogotá, Colombia (2,550 meters). I conclude that stadium altitudes should not be restricted under 3,000 meters without further justification.

1 Introduction

In 2007, the Fédération Internationale de Football Association (FIFA) announced a ban on international soccer matches above 2,500 meters (8,200 feet) unless the away team had adequate time to acclimatize. This limit excluded Bolivia, Colombia, and Ecuador from hosting matches in their capital cities. The South American soccer federation CONMEBOL and most of its member countries backed their high neighbors; 47 year old former star Diego Maradona even led an Argentinian side in an exhibition against a Bolivian side headed by President Evo Morales at 3,600 meters in La Paz to prove the point. Under heavy pressure, FIFA suspended the ban in May, 2008.

During this period, FIFA held a conference to discuss the impacts of altitude on soccer team performance. The conference participants agreed [1] that altitude change impacts the behavior of a kicked ball and has negative effects on physical performance. The primary negative effects of traveling up are aerobic, due to lower oxygen levels at high altitude, but acute mountain sickness can cause devastating effects, even at 4,000 meters or lower. To achieve peak physical capacity, most participants recommended [1] that soccer players spend one to two weeks acclimatizing before matches above 2,000 meters and at least two weeks acclimatizing before matches above 3,000 meters. Scientific studies [2] also suggest that traveling to lower altitude can harm performance. Despite this consensus, negative physiological effects could be small for professional athletes within reasonable altitude ranges. Acclimatization procedures such as those recommended by the FIFA conference can also mitigate negative effects of traveling up.

FIFA has primarily been interested in whether high altitude matches are fair; to inform this debate, I investigate whether altitude change has any measurable impact on team performance. I analyze match outcomes from more than 100 years of international soccer in South America, where matches are played at altitudes ranging from sea level to over 4,000 meters. Previous research using similar data [2] finds that teams traveling either up or down win less often than teams that do not change altitude. These results imply fairness concerns with playing at any altitude – concerns that perhaps balance out. However, the estimates may be biased since there are no controls for characteristics of the away teams. In fact, another study [3] that controls for team characteristics and environmental factors using 10 years of recent South American data finds no effect of altitude change on away team performance. Using a longer time series, I compare matches between the same home and away teams but played at different altitudes within the host country. This approach holds all team-specific factors constant while allowing altitude to vary; any remaining disparities in match outcomes should be attributable to altitude differences.

I find that traveling down has no impact on match outcomes, but traveling up has a negative, linear effect on away team performance on average. I explore these results further by comparing matches between the same teams played at low and high altitude in Bolivia, Colombia, and Ecuador, country by country. FIFA's initial upper altitude limit was just below Colombia and Ecuador's main stadium altitudes, so these comparisons are policy relevant. Teams play worse in Ecuador when they must travel up to Quito (2,800 meters), but they actually play better when traveling up to Bogotá (2,550 meters) to play Colombia. Visiting teams' effectiveness at altitude against Colombia suggests that FIFA does not need to cap altitude in the 2,500 to 3,000 meter range. Teams struggle mightily when traveling up to 3,600 meters in La Paz, Bolivia (rather than playing at 400 meters in Santa Cruz), but I refrain from making policy recommendations at this altitude level since my analysis relies on a single country.

2 Data and Results

The match data for this study come from the The Rec.Sport.Soccer Statistics Foundation archive (copyrights and data URLs can be found in Appendix A). This archive has score and match location data for all international matches played by the top ten South American countries from 1902 to 2009: Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Paraguay, Peru, Uruguay, and Venezuela. I exclude neutral site matches. I obtained city latitudes and longitudes in order to link the match data to precise GPS altitude data. If a city had multiple altitudes in the database, I took the average altitude. In order to calculate altitude differences for the away team, I compare their capital city altitude to the match altitude, except in the case of Brazil. For Brazil, I use Rio de Janeiro's altitude instead of Brasilia, since Brazil plays most matches in Rio de Janeiro.

Previous work with FIFA data [2] estimated the following ordinary least squares regression model:

$$W_i = \alpha + \gamma' H_i + \beta_1 I_i + \beta_2 I_i^2 + \varepsilon_i, \quad (1)$$

where W_i is a dummy for a home win, H_i is a vector of dummies for the home team, and I_i is the increase in altitude for the away team (negative if the team traveled down), using each country's main

Table 1. Effects of Away Team Altitude Change, Home Dummies Only

	Home Win (1)	Home Goals (2)	Away Goals (3)	Home Goals – Away Goals (4)
Altitude increase, away team (km)	-0.008 (0.007)	-0.057 (0.038)	0.037* (0.023)	-0.094** (0.045)
Altitude increase, away team (km)^2	0.018*** (0.002)	0.048*** (0.010)	-0.027*** (0.008)	0.075*** (0.013)
Observations	1,551	1,551	1,551	1,551

Notes: The table presents OLS regressions of match outcomes (listed across the top row) on a quadratic in the away team altitude increase (negative if a decrease). The away team altitude increase equals the difference between the match altitude and the away team's capital city altitude (except for Brazil, which plays primarily in Rio de Janeiro). All columns include a full set of home team dummy variables. Each observation represents one match. I employ two-way clustered standard errors at the year and matchup level.

stadium altitude for all matches. The regression analysis yields a positive and statistically significant coefficient on the square of the altitude increase. The authors use these estimates to calculate that traveling up 2,000 meters has little impact on match outcomes, but an away team increase of 4,000 meters increases home team winning percentage by about 8 percent. An away team decrease of 4,000 meters increases home team winning percentage by about 27 percent.

Table 1 replicates these results for the 1,551 matches in my data, using the exact altitude for every match. As in the previous study, I estimate that the square of the away team's altitude increase has a statistically significant positive effect on win probability (column 1). I compute effects of altitude change on home goals, away goals, and the score differential in columns 2 through 4, with similar results. The estimates confirm that my data do not differ substantially from the FIFA data, but the results from either dataset are likely biased due to differences between away teams that travel up or down. For example, this statistical approach attributes differences in Bolivia and Argentina's performances in Brazil entirely to altitude changes, even though Bolivia and other high altitude countries must also travel farther than most lowlanders in order to play in Brazil. Any away team characteristics (such as travel distance) that are correlated with altitude change and with match outcomes will lead to bias in the estimated altitude effects.

In table 2, I reduce potential biases by including a full set of interactions between home and away team dummy variables. Effects from this specification tell us whether altitude changes influence matches between the same home and away team. For example, this approach compares match outcomes between Ecuador and Brazil played in Quito, Ecuador (2,800 meters), versus Guayaquil, Ecuador (sea level). In this comparison, the home and away teams are the same, and Brazil faces similar travel requirements, so I can attribute any disparity in match outcomes to the altitude difference. I drop 277 matches from the data because some pairs of teams always play at the same altitude.

The estimates in panel A of table 2 show that traveling up or down has little influence on match outcomes. The effects are of the same sign as in table 1 but they are much smaller and estimated less precisely. The only marginally significant result is the effect of the squared altitude increase on goal differential (column 4). The positive sign on this coefficient implies that teams traveling up or down lose by more goals than teams that do not change altitude, but the effect

Table 2. Effects of Away Team Altitude Change, Home and Away Interactions

	Home Win (1)	Home Goals (2)	Away Goals (3)	Home Goals – Away Goals (4)
	Panel A. Quadratic Specification			
Altitude increase, away team (km)	0.008 (0.037)	0.036 (0.073)	-0.011 (0.054)	0.048 (0.104)
Altitude increase, away team (km)^2	0.015 (0.010)	0.022 (0.018)	-0.022 (0.016)	0.044* (0.027)
	Panel B. Two-Sided Linear Specification			
Altitude decrease, away team (km)	0.039 (0.081)	0.060 (0.143)	-0.073 (0.079)	0.134 (0.197)
Altitude increase, away team (km)	0.055*** (0.021)	0.112* (0.061)	-0.083 (0.076)	0.194* (0.107)
Observations	1,274	1,274	1,274	1,274

Notes: The table presents OLS regressions of match outcomes (listed across the top row) on a quadratic in the away team altitude increase (negative if a decrease) in panel A and separate linear terms for the away team altitude increase or decrease in panel B. The away team altitude increase equals the difference between the match altitude and the away team's capital city altitude (except for Brazil, which plays primarily in Rio de Janeiro). All columns include full interactions of home team and away team dummy variables. Each observation represents one match. I employ two-way clustered standard errors at the year and matchup level and exclude matches in which the two teams only played at one altitude within a country (the altitude difference is perfectly collinear with the home and away interaction in that case).

is not large enough to generate a significant effect on winning or losing (column 1).

These results suggest that altitude changes are not very important, but there may still be specification error. A quadratic form artificially forces the effects of traveling up or down to be on the same curve. In panel B of table 2, I estimate separate linear effects of traveling up or down as follows:

$$W_i = \alpha + \gamma'(H_i \times A_i) + \beta_1(I_i \times 1[I_i > 0]) + \beta_2(-I_i \times 1[I_i < 0]) + \varepsilon_i. \quad (2)$$

Here, β_1 is the effect of traveling up and β_2 is the effect of traveling down, which can be estimated independently. The $H_i \times A_i$ term represents the interactions between home and away team dummies.

Column 1 of panel B in table 2 shows that home team winning percentage increases by over 5 percent for each 1,000 meters that the away team must climb. This estimate is statistically significant at the one percent level. Effects on goals scored in columns 2 through 4 also suggest large negative effects of traveling up, although they are not estimated precisely. Traveling down has no statistically significant impact on match outcomes.

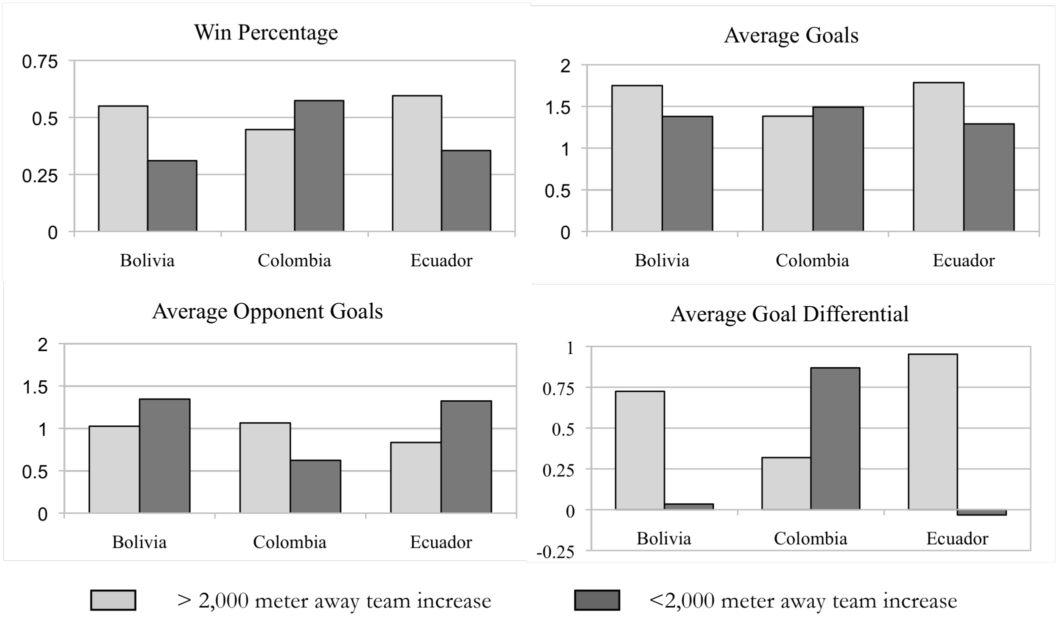

Figure 1. High Altitude Home Team Outcomes by Away Team Altitude Change

These results provide support for an altitude limit. However, the two-sided linear specification is unlikely to be perfect. Climbing 1,000 meters is probably not enough to generate a 5 percent increase in home winning percentage, while climbing 4,000 meters might change winning percentage by even more than 22 percent. Estimating separate quadratic functions for traveling up and down would increase flexibility further, but within-country altitude does not vary enough to fit such functions precisely. Since FIFA has primarily been interested in whether altitude increases hurt performance at or above 2,500 meters, I instead focus on matches played in Bolivia, Colombia, and Ecuador.

In all three countries, most matches are played at a single high altitude site, but a substantial number are played near sea level. Figure 1 shows that, in Bolivia and Ecuador, teams that climbed at least 2,000 meters for a match fared much worse than teams that did not. Both home countries won over 50 percent of their matches against climbing teams (mostly matches in La Paz and Quito) but only around 30 percent of their matches against teams that did not climb (mostly matches in Santa Cruz and Guayaquil). However, Colombia shows the opposite pattern, winning just 45 percent of their matches against climbing teams (mostly in Bogotá) but 57 percent against teams that did not climb (mostly in Barranquilla). These simple statistics do not control for away team characteristics, but regressions including home and away team interactions (as in Table 2) along with a dummy variable for climbing over 2,000 meters yield similar results.

3 Conclusions

Using a two-sided linear regression model on over 100 years of match data, I find that home teams have a distinct advantage in South American international soccer when away teams travel up for a match. In contrast with previous work with this data [2], I find that traveling down has no impact on match outcomes. Country-specific analysis shows that away teams have had success playing Colombia at an altitude of 2,550 meters, even when comparing match outcomes in Colombia for the same away team. Traveling up just 250 meters farther to Quito, Ecuador, generates a large negative effect, and this effect persists at 3,600 meters in Bolivia. Future work should consider whether differences in opponent quality or other aspects of home field advantage can explain these differences. For example, it could be that Colombia has chosen to play its toughest opponents in Bogotá, depressing their high altitude winning percentage. Or, Ecuador and Bolivia may benefit from raucous crowds and better player accommodations in Quito and La Paz, inflating their high altitude winning percentage.

Still, away teams' success at over 2,500 meters in Colombia should give FIFA pause when considering an altitude restriction under 3,000 meters. Although Bolivia appears to have a strong advantage at 3,600 meters, I advise looking at these results in close detail and collecting more data before using them to justify a limit over 3,000 meters. My statistical findings do not take ethical arguments into consideration, either. High altitude is part of many countries' culture, and other environmental factors remain largely unregulated (e.g., temperature, humidity, and air quality). While it seems that there is some advantage to playing at altitude, any decision on a restriction must take all of these factors into account.

4 Acknowledgments

I thank Griffin Williams for supreme assistance with data collection.

5 References

[1] Peter Bärtsch et al., "Consensus Statement on Playing Football at Different Altitude," Scandinavian Journal of Medicine & Science in Sports, vol. 18, Supplement 1, pp. 96-99, 2008.
[2] C. J. Gore et al., "Preparation for Football Competition at Moderate to High Altitude," Scandinavian Journal of Medicine & Science in Sports, vol. 18, Supplement 1, pp. 85-95, 2008.
[3] Rómulo A. Chumacero, "Altitude or Hot Air," Journal of Sports Economics, vol. 10, no. 6, pp. 619-638, December 2009.

A Appendix: Data Sources and Copyrights

South American international match data:
Argentina: © Copyright Héctor Darío Pelayes and RSSSF 1998/2009
Bolivia: © Copyright Marcelo Leme de Arruda, RSSSF and RSSSF Brazil 2002/2009
Chile: © Copyright Frank Ballesteros, Luis Antonio Reyes and RSSSF 2000/2005
Colombia: © Copyright Frank Ballesteros and RSSSF 1999/2009
Ecuador: © Copyright Fernando Espinoza Añazco and RSSSF 2003/2009
Paraguay: © Copyright Frank Ballesteros, Eli Schmerler and RSSSF 2000/2006
Peru: © Copyright José Luis Pierrend and RSSSF 1998/2009
Uruguay: © Copyright Martín Tabeira and RSSSF 2002/2009
Venezuela: © Copyright Frank Ballesteros, José Luis Pierrend, Eli Schmerler and RSSSF 1998/2006

Latitude and longitude for cities:
http://www.kingwoodcable.com/gpswaypoints/index.htm

Altitude data:
http://www.gpsvisualizer.com/elevation
http://www.gpsvisualizer.com/elevation.html