


CONMEBOL Libertadores Cup: Altitude impact on goals and results in 16 years of soccer matches

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ABSTRACT

Background: The CONMEBOL Libertadores Cup, is the continent's most important international club tournament. Teams are exposed to different altitudes with short acclimatization periods. The present study describe the effect of altitude on the results and goals of soccer club teams matches between 2000 and 2015 in the CONMEBOL Libertadores Cup. **Materials & Methods:** All home and away matches from the group phase onwards and which have been played at the traditional team venue were taken into account, thus, 2039 games were analysed. The teams were classified into altitude categories according to the physiological impact and registered hometown altitude. A Poisson's generalized linear model was used to study the relationship between the altitude of both home and away teams and the number of goals scored for each team according to the altitude category. The probabilities that the home team winning, drawing, or losing the match were estimated using a regression model for ordinal variables and assuming a multinomial probability distribution with the logistic linkage. Factors as heat, temperature and general performance of the teams were not considered. **Results:** Home team scores more (2.62 goals) when the away team descends three altitude categories, followed by a descent of two altitude categories (2.01 goals) and an ascent of three altitude categories (1.89 goals). This is associated with an increase probability of winning for the home team, being 5.5 times more likely when the away team descends three altitude categories, 2.3 times more when it descends two categories, and 2.5 times more when it ascends three altitude categories. **Conclusions:** These findings suggest that the away team is more likely to lose a match when it has to descend two or three altitude categories and when it ascends three altitude categories.

Keywords: Soccer; High altitude; Performance.

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INTRODUCTION

As altitude increases, hypoxia, cold, and dehydration may cause respiratory distress, headaches, nausea, dizziness, and fatigue. Soccer can exacerbate these symptoms and prevent players from performing at their best (Levine et al., 2008; Povea et al., 2005). Reduced performance appears in different physical parameters such as a shorter total distance travelled, a shorter distance travelled at high speed, an increase in the fatigue index, and a decrease in the ability to make repeated high-intensity efforts. These changes begin to appear at 1200 meters above sea level (m.a.s.l.) (Aughey et al., 2013; Billaut and Buchheit, 2013; Nassis, 2013; Garvican et al., 2014). Bärtsch et al (2008) in their consensus on playing football at different altitudes describe five different altitude categories involving different symptoms and levels of poor performance (Table 1).

Acute exposure to hypoxia, described as a reduction in inspired pressure of oxygen as a result of the decreased atmospheric pressure, causes a decrease in arterial oxygen saturation (Gore et al., 2008). This leads to an adaptive physiological response that is reflected as an increase in respiratory rate, ventilation, heart rate, and the respiratory equivalent of oxygen ($\dot{V}E/\dot{V}O_2$) (Gore et al., 2008). Also, an increase in altitude is associated with a decrease in the value of $\dot{V}O_{2max}$ (Brutsaert et al., 2000b). Moreover, a reduction in air density at altitude facilitates sprints and alters the aerodynamics of flying objects (such as a soccer ball), which affects a player's technical skills (Levine et al., 2008; Nassis, 2013).

Currently, few studies highlight the difficulties of playing soccer at altitude and its effect on performance. Nassis (2013) described that the total distance travelled during a match was 3.1% less in matches played at altitudes above 1200 m.a.s.l. compared to the values at sea level during the 2010 FIFA World Cup. Similarly, the performance of the teams at altitudes between 950 m.a.s.l. and 1700 m.a.s.l. was better than that of those teams at sea level during the 2010 FIFA World Cup (Faude et al., 2011). Notwithstanding, we cannot guarantee that altitude will be an advantage for the home team.

Nassis (2013) and Tovar (2014) state that the maximum speed of players and their number of goals scored, and mistakes made by goalkeepers leading to goals are not significantly influenced by altitude. Plus, the authors found no differences attributable to altitude in various technical aspects such as total number of passes, number of passes in the rival field, and number of successful passes when comparing matches in the 2013 CONMEBOL Libertadores Cup. This might be explained, among other things, by the intrinsic uncertainty of soccer matches and the innumerable extrinsic variables associated with their development and outcome (Gore et al., 2008; Girard et al., 2013).

Concerning high-altitude residents, they often report discomfort and dizziness when descending to low altitudes and may be affected by increased air density (Gore et al., 2008; Gore et al., 2013; Hörzer et al., 2010). Some studies have shown that movements between altitudes below 2000 m.a.s.l. both ascending and descending, may be irrelevant for the soccer players (Gore et al., 2008; Nassis, 2013; Levine et al., 2008; Faude et al., 2011). Nevertheless, when the movement is higher than 2000 m.a.s.l., the probability of winning for the home team increases. This behaviour is more evident when the away team descends in altitude (Gore et al., 2008; Nassis, 2013; Levine et al., 2008; Faude et al., 2011).

The previous investigations include only matches and tournaments organized by FIFA for national soccer teams, and these do not comply with such a rigid competition schedule compared to professional soccer clubs. The FIFA Medical Sports Committee suggests acclimatization periods of 3-14 days from 1500 m.a.s.l. in their guidelines for training and competition at different altitudes (Bärtsch et al., 2008). Due to the tight

competitive schedule and logistical requirements, these recommendations are difficult for clubs to meet, and most choose to travel 24 or 12 hours before the match.

The South American Soccer Confederation (CONMEBOL from its Spanish initials) comprises ten South American nations and organizes the CONMEBOL Libertadores Cup, the continent's most important international club tournament. During the tournament, participating teams play against each other in a format that involves both home and away fixtures (<https://www.conmebol.com/>). Due to the geographical conditions of the continent, the participating soccer teams are exposed to different environmental conditions such as temperature, humidity, and altitudes. The fact that four of the five altitude categories described by Bärtsch et al. (2008) are found in South America makes this phenomenon more frequent than in other competitions.

For the previous reasons, this study aimed to describe the effect of altitude on the results and goals of soccer club teams matches between 2000 and 2015 in the CONMEBOL Libertadores Cup.

MATERIALS AND METHODS

CONMEBOL Libertadores Cup

The CONMEBOL Libertadores Cup is an international tournament that has been held since 1960, where the best teams from the national soccer league members that make up CONMEBOL participate. Since 2000, 32 teams have participated in the tournament as part of the group stage, except the 2004 tournament where 36 teams participated. These teams are distributed by drawing lots in groups of four teams each, where the participants play each other in home and away fixtures. The top two teams in each group go on to the next knockout round; therefore, 16 teams remain in competition in a knockout phase that also includes both home and away fixtures.

As an inclusion criterion for the analysis, all home and away matches from the group phase onwards and which have been played at the traditional team venue were taken into account. Thus, 2039 games were analysed.

The name of the teams, the place where the match was held, the stage of the tournament, the goals scored by both teams, the final result of the game (win, draw, or lose), and the home or away status were recorded for each of the teams in each game. This information was obtained from https://www.resultados-futbol.com/copa_libertadores. This study was approved by the Institutional Ethics Committee of the University Institution Escuela Nacional del Deporte, Cali, Valle, Colombia.

Altitude

Information on the city where the team usually plays was obtained from the official website of each team. Then, the official website of the city was used for the average altitude reported in m.a.s.l.

Table 1. Altitude category for home and away team.

Altitude (m.a.s.l.)	Altitude category
0 to 500	Sea level (A)
501 to 2000	Low altitude (B)
2001 to 3000	Moderate altitude (C)
3001 to 5500	High altitude (D)
Greater than 5500	Extreme altitude (E)

Note. m.a.s.l.: meters above sea level.

The teams were classified into altitude categories according to the parameters set by Bärtsch et al. (2008) (Table 1).

The analysis of the data was based on combinations determined by the change in the altitude category of the away team. Seven groups of combinations were established (Table 2).

Table 2. Group combinations according to altitude category.

Group	Combinations
SA	(A,A); (B,B); (C,C); (D,D)
Asc ₁	(B,A); (C,B); (D,C)
Asc ₂	(C,A); (D,B)
Asc ₃	(D,A)
Des ₁	(A,B); (B,C); (C,D)
Des ₂	(A,C); (B,D)
Des ₃	(A,D)

Note. SA: same altitude category; Asc₁: away ascends one altitude category; Asc₂: away ascends two altitude categories; Asc₃: away ascends three altitude categories; Des₁: away descends one altitude category; Des₂: away descends two altitude categories; Des₃: away descends three altitude categories; A: sea level; B: low altitude; C: moderate altitude; D: high altitude.

The matches played in a neutral stadium and not in the host city of the home team were not included in the analysis, as it was considered that both teams might be exposed to the change in altitude.

Statistical analysis

The statistical software R (version 3.0.1) was used for all statistical analyses. The results of the inferential analysis are presented using estimated means with their standard errors and confidence intervals. A Poisson's generalized linear model was used to study the relationship between the altitude of both home and away teams and the number of goals scored for each team according to the altitude category. The probabilities that the home team winning, drawing, or losing the match were estimated using a regression model for ordinal variables and assuming a multinomial probability distribution with the logistic linkage. Two models were fitted. The first one (model 1; L/TW) assuming as response variable the log of the odds formed with the quotient between the probability of lost and the probability of win or draw and the second one (model 2; LT/W) assuming as response variable the log of the odds formed with the quotient between the probability of lost or draw over the probability of win. Given the symmetry in the probabilities, both models estimated the same parameters and only the intercepts were different. To study the effect of the difference in altitude, the OR was estimated. The OR is an index used in epidemiologic studies to evaluate the force of the association between two categorical variables. In this case the OR allows have an idea about the force in the relationship between the change in the altitude and the result obtained by the home team. To assess compliance with the theoretical assumptions required by the models, the parameter of over-dispersion in the expected number of goals (Poisson's model) was estimated. The goodness of fit of the models was evaluated using the likelihood ratio test and the deviation test. A maximum value of .05 was assumed for the type I error, in the results we report 95% confidence intervals and we used the 97.5 percentile to reject the hypothesis assuming a two side tall test.

RESULTS

The average change in altitude (m.a.s.l) and the total number of matches according to altitude category are presented in Table 3.

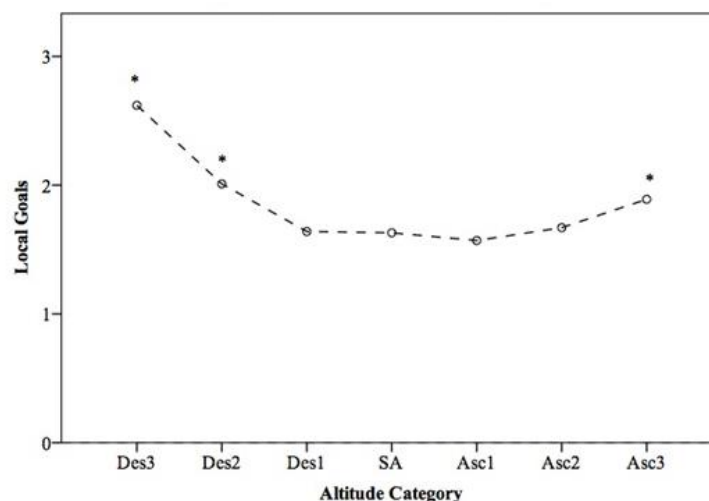
Table 3. Average change in altitude and total matches according to altitude category.

Group	Description	Matches
SA	No change in altitude	769
Asc ₁	Away ascends 1023 m.a.s.l.	391
Asc ₂	Away ascends 2543 m.a.s.l.	189
Asc ₃	Away ascends 3605 m.a.s.l.	55
Des ₁	Away descends 1022 m.a.s.l.	392
Des ₂	Away descends 2544 m.a.s.l.	188
Des ₃	Away descends 3605 m.a.s.l.	55

The total number of goals scored at the end of a match is expected to be a minimum of two goals for the home team when the away team ascends the equivalent in meters to three FIFA altitude categories (1.89; CI: 1.55-2.27) or descends the equivalent of two (2.01; CI: 1.80-2.21) or three of these categories (2.62; CI: 2.21-3.06) (Figure 1A). On the other hand, the away team has an estimated probability of scoring less than one goal when descending the equivalent of two (0.71; CI: 0.59-0.83) or three of these categories (0.40; CI: 0.25-0.59) (Figure 1B).

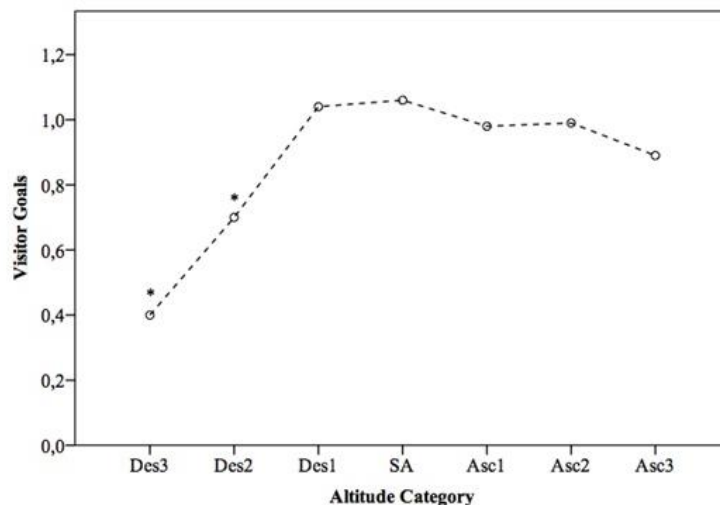
By analysing the probability of scoring goals according to the home or away status. Descending three altitude categories gives the home team the highest probability of scoring goals and the away team the lowest probability in contrast with other altitude categories.

The home team has a probability of scoring three or more goals and a low probability of scoring one or zero goals when the away team descends three altitude categories. While the probability of scoring two goals is similar in all altitude combinations (Figure 2A).



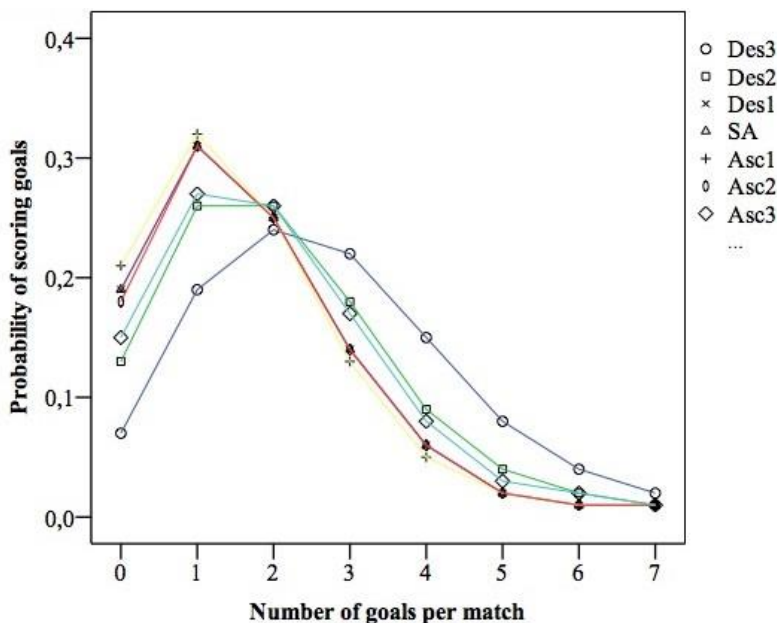
Note. SA: same altitude category; Asc₁: away ascends one altitude category; Asc₂: away ascends two altitude categories; Asc₃: away ascends three altitude categories; Des₁: away descends one altitude category; Des₂: away descends two altitude categories; Des₃: away descends three altitude categories: * $p < .05$.

Figure 1A. Home team expected goals according to altitude category.



Note. SA: same altitude category; Asc₁: away ascends one altitude category; Asc₂: away ascends two altitude categories; Asc₃: away ascends three altitude categories; Des₁: away descends one altitude category; Des₂: away descends two altitude categories; Des₃: away descends three altitude categories: * p < .05.

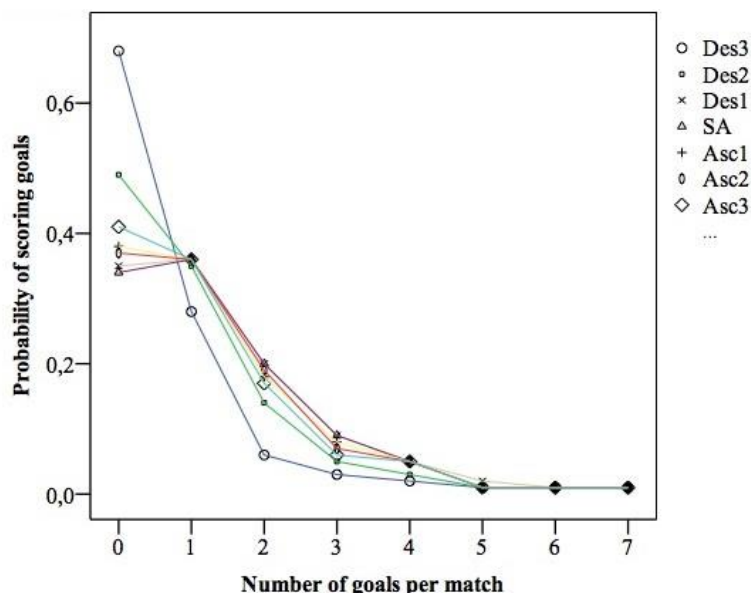
Figure 1B. Away expected goals according to altitude category.



Note. SA: same altitude category; Asc₁: away ascends one altitude category; Asc₂: away ascends two altitude categories; Asc₃: away ascends three altitude categories; Des₁: away descends one altitude category; Des₂: away descends two altitude categories; Des₃: away descends three altitude categories.

Figure 2A. Estimated probability for home team to score goals according to altitude category.

The probability of the away team not scoring any goals is always more than 30%. It is higher (50%) when there is a descent from two altitude categories and the highest (70%) when there is a descent from three altitude categories. The probability of the away team scoring one or more goals is always lower at descents from three altitude categories compared to other combinations (Figure 2B).



Note. SA: same altitude category; Asc₁: away ascends one altitude category; Asc₂: away ascends two altitude categories; Asc₃: away ascends three altitude categories; Des₁: away descends one altitude category; Des₂: away descends two altitude categories; Des₃: away descends three altitude categories.

Figure 2B. Estimated probability for away team to score goals according to altitude category.

The final result of the match (win, draw, or lose) was also influenced by the change in altitude. When the away team descends three altitude categories, the home team's odds of winning the match increase 5.5 times. When it descends two categories, the odds of winning for the home team increase 2.3 times. A similar result is obtained when the away team ascends three altitude categories, increasing the home team's odds of winning 2.5 times (Table 4).

Table 4. Odds of winning for the home team according to altitude category.

Altitude Category	Estimate	Standard Error	p-value	CI 95%	OR _j = e ^{β_j}
Intercept L/TW	-1.141	0.075	-	-1.288; -0.99	-
Intercept LT/W	-0.069	0.060	-	-0.206; -0.068	-
Asc 1	-0.0007	0.118	.99	-0.229; 0.231	0.999
Asc 2	-0.025	0.154	.87	-0.278; 0.327	0.975
Asc 3	-0.198	0.307	.002	0.317; 1.519	0.399 [◇]
Des 3	-1.702	0.388	<.001	0.943; 2.462	0.182*
Des 2	-0.838	0.173	<.001	0.499; 1.178	0.432 [†]
Des 1	0.065	0.118	.58	-0.168; 0.298	0.937

Note. CI 95%: 95% confidence interval; OR: odds ratio estimation; L/TW: intercept for model 1; LT/W: intercept for model 2; *: home team odds of winning the match increase 5.5 times; †: home team odds of winning the match increase 2.3 times; ◇: home team odds of winning the match increase 2.5 times.

DISCUSSION

The impact of altitude on sports performance has traditionally been focused on the physiological response to acute and chronic exposure to hypoxic conditions, both for training and competition for the away team (Levine et al., 2008; Aughey et al., 2013; Gore et al., 2013; Girard and Pluim, 2013). Contrary to expectations, the main finding of this study suggests that descending has a greater impact on performance.

One of the conditions that has been considered a priori and that may affect sports performance is the advantage for the team playing at home. Gore et al. (2008) and Chumacero (2009) found that for South American teams, the home status may be a determining factor in the percentage of victories (57%). This pattern is also observed at the level of European soccer clubs, where the home team won around 55% of the matches (Saavedra García et al., 2013). In this study, the multinomial regression model shows that the home team has an estimated probability of winning more than 50%. Nevertheless, when an away club descend from more than two altitude categories, the estimated probability of winning by the home team increases to more than 71%, even reaching 85% when the away team descend from three categories. In contrast, when the away team ascend three categories the probability of winning by the home team is 72%. This is similar to the behaviour reported by Gore et al. (2008) when studying South American teams over 100 years, where teams that descended from high and moderate altitude to sea level had a 73% probability of losing.

Saavedra García et al. (2013) reported that, during European clubs' matches, 23.9% are drawn. Our results show an estimated probability of a draw between 16 and 25%. However, the probability of a draw in a match is only 9% when the away team has to descend three altitude categories.

In this study, it was observed that the home team is more likely to score goals than the away team. However, when assessing the goals scored considering the effect of altitude, away teams are less likely to score when they have to descend two or three altitude categories. Similarly, away teams are less likely to score when they have to ascend three altitude categories. Chumacero (2009) and Nassis (2013) found no impact of altitude on goals scored during South American team matches and World Cup matches in South Africa, respectively.

The discrepancy between the results of this study and those described by Chumacero (2009) and Nassis (2013) might derive from the population studied. Their findings are mainly based on national teams during qualifying rounds (Chumacero, 2009; McSharry, 2007) and World Cup matches (Nassis, 2013), whereas the present study analysed the behaviour of soccer clubs during a long tournament. Home clubs have an advantage during acclimatization periods as they usually train and compete in the same place and environment for an entire season. On the contrary, national teams are limited to a few days of concentration for training and competition, in addition to the problem that players come from different clubs around the world and have a variety of individual conditions. This might influence the outcome of the game as a result of the individual physiological response to changes in each environmental condition (Mureika, 2006; Levine et al., 2008).

Changes in environmental conditions, such as exposure to hypoxia, have a physiological impact on the availability of mitochondrial oxygen and therefore on the production of ATP (Levine et al., 2008), evident from 600 m.a.s.l (Gore et al., 1997). The $\dot{V}O_{2peak}$ value in soccer players is lower at high altitudes compared to those at sea level, regardless of the acclimatization of the player to hypoxic conditions (Brutsaert et al. 2000a).

As a way to compensate for the physiological impact of exposure to hypoxia, a decrease in some activities has been observed (Aughey et al., 2013), such as the pace and intensity of play to reduce the degree of perceived fatigue (Brocherie et al., 2017; Buchheit et al., 2013), which reduces the distance travelled during the match (Aughey et al., 2013; Gore et al., 1997; Brutsaert et al., 2000a; Levine et al., 2008). Tucker et al. (2004) considered that the conscious perception of effort has a regulatory role when competing in hypoxic conditions. This statement coincides with the observations made by Tovar (2014), who reported an increase

in the percentage of successful passes made by each player in his half during soccer games above 2500 m.a.s.l in the CONMEBOL Libertadores Cup.

It is worth noting that high-intensity activities have proven to be crucial to soccer performance and the outcome of a game (Di Salvo et al., 2009; Faude et al., 2012; Sarmiento et al., 2014). These activities have not been shown to decrease during exposure to hypoxia (Nassis 2013; Garvican et al., 2014) and could be explained by a reduction in air density in higher altitudes (3% for every 305 m.a.s.l), this causes that both the athlete and the soccer ball experience a reduced air resistance during a match (Mureika, 2006, Levine et al., 2008, Haugen and Buchheit, 2015).

Changes in environmental conditions also affect the teams that have to descend in altitude. Regarding $\dot{V}O_{2peak}$ values, the natives at altitude have an increase when descending to sea level (420 m.a.s.l.) even so, these values do not show significant differences with those of the sea-level natives. However, the decrease in altitude generates an expansion of plasma volume, which may be associated with peripheral edema and an increase in the weight of the player, generating a higher energy cost for specific motor activities (Böning, 1997). Besides, there is no physiological advantage with the decrease in the regeneration of ATP and phosphocreatine (Brutsaert et al., 2000a). This could explain why the performance of high-intensity activities such as the 20-m sprints does not improve in descending athletes compared to the performance of sea-level natives (Buchheit et al., 2013; Girard et al., 2017).

On the other hand, the air density affects the athlete's movement and impacts on dynamic force components that act on elements such as the ball. Within these components, we can find the air drag coefficient (the force that acts against the flight direction of the soccer ball) and the Magnus force coefficient (difference of fluid pressure on opposite sides of the rotating object), both directly proportional to air density (Haugen and Buchheit, 2015). When the drag coefficient increases, the ball moves a shorter distance with the same force applied compared to this action at a higher altitude. Also, the increase in Magnus' force coefficient results in a greater spin of the ball, causing a greater curvature in its trajectory, which makes it move further away from its linear trajectory and generates less precision in the control and the trajectory of the ball (Hörzer et al., 2010). At altitude, where there is less barometric pressure, the distance travelled by the ball is greater and there is less spin, which generates greater precision in its control (Hörzer et al., 2010). This may become important in sports practice where the degree of technical skill largely determines the success of the competition (Levine et al., 2008).

Taking into account the short time for players to acclimatize to the degree of accuracy in ball control, this might explain our findings, where teams that have to descend more than two altitude categories were less likely to score goals and more likely to concede them. Thus, descent and ascent at altitude might be a disadvantage for the away team during soccer matches, mainly for those descending.

CONCLUSIONS

This study showed that altitude could have an impact on sports performance in South American soccer clubs participating in the CONMEBOL Libertadores Cup, based on the number of goals scored, the number of goals conceded, and the results of the matches. These findings suggest that the away team is more likely to lose a match when it has to descend two or three altitude categories and when it ascends three altitude categories. This translates into a lower probability of scoring goals and a higher probability of receiving them, which may reflect the physiological impact of a change in altitude and the impact of a change in environmental conditions, including the air resistance coefficient and the Magnus force coefficient.

This study has certain limitations. In the database analysed, no information was obtained from other types of variables that could impact the result of the matches, such as technical aspects, tactical aspects, or some environmental conditions (temperature and humidity). Therefore, the results reported can be considered as a first approximation in the analysis of the effect of altitude changes in soccer clubs.

AUTHOR CONTRIBUTIONS

Moisés A. Cabrera, Sergio A. Garcia-Corzo, Luis J. Tafur and Camilo. E. Povea has given substantial contributions to the conception and the design of the manuscript. Hugo Hurtado, Daniel F. Grijalba, Carlos A. Mosquera and José R. Tovar helped in the analysis, and interpretation of the data. Carlos A. Mosquera and Daniel F. Grijalba made support in the statistical processing of the data and results. José R. Tovar approach to the methodological proposal to organize the data file and make the statistical analysis of the same. All authors have participated in drafting the manuscript. Moises A. Cabrera, Sergio A. Garcia-Corzo, Luis J. Tafur and Camilo. E. Povea revised it critically. All authors contributed equally to the manuscript and read and approved the final version of the manuscript. All co-authors have reviewed and approved the manuscript prior to submission.

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REFERENCES

- Aughey RJ, Hammond K, Varley MC, Schmidt WF, Bourdon PC, Buchheit M, Simpson B, Garvican-Lewis LA, Kley M, Soria R, Sargent C, Roach GD, Claros JCJ, Wachsmuth N, and Gore CJ (2013). Soccer activity profile of altitude versus sea-level natives during acclimatization to 3600 m (ISA3600). *Br J Sports Med* 47:i107-i113. <https://doi.org/10.1136/bjsports-2013-092776>
- Bärtsch P, Saltin B, and Dvorak J (2008). Consensus statement on playing football at a different altitude. *Scand J Med Sci Sports* 18:96-99. <https://doi.org/10.1111/j.1600-0838.2008.00837.x>
- Billaut F and Buchheit M (2013). Repeated-sprint performance and vast lateralis oxygenation: Effect of limited O₂ availability. *Scand J Med Sci Sports* 23:e185-e193. <https://doi.org/10.1111/sms.12052>
- Böning D (1997). Altitude and Hypoxia Training - A Short Review. *International Journal of Sports Medicine* 18:565-570. <https://doi.org/10.1055/s-2007-972682>

- Brocherie F, Millet GP, and Girard O (2017). Psychophysiological Responses to Repeated-Sprint Training in Normobaric Hypoxia and Normoxia. *Int J Sports Physiol Perform* 12:115-123. <https://doi.org/10.1123/ijsp.2016-0052>
- Brutsaert T, Spielvogel H, Soria R, Araoz M, Caceres E, Buzenet G, Villena M, Paz-Zamora M, and Vargas E (2000a). Environmental Exercise Physiology Performance Of Altitude Acclimatized And Non-Acclimatized Professional Football (Soccer) Players At 3,600 M. *J. Exerc. Physiol. Online* 3:28-37.
- Brutsaert TD, Araoz M, Soria R, Spielvogel H, and Haas JD (2000b). Higher arterial oxygen saturation during submaximal exercise in Bolivian Aymara compared to European sojourners and Europeans born and raised at high altitude. *Am. J. Phys. Anthropol* 113:169-181. [https://doi.org/10.1002/1096-8644\(200010\)113:2<169::AID-AJPA3>3.0.CO;2-9](https://doi.org/10.1002/1096-8644(200010)113:2<169::AID-AJPA3>3.0.CO;2-9)
- Buchheit M, Simpson BM, Garvican-Lewis LA, Hammond K, Kley M, Schmidt WF, Aughey RJ, Soria R, Sargent C, Roach GD, Claros JCJ, Wachsmuth N, Gore CJ, and Bourdon PC (2013). Wellness, fatigue, and physical performance acclimatization to a 2-week soccer camp at 3600 m (ISA3600). *Br J Sports Med* 47:i100-i106. <https://doi.org/10.1136/bjsports-2013-092749>
- Chumacero RA (2009). Altitude or Hot Air? *J Sports Econom* 10:619-638. <https://doi.org/10.1177/1527002509336217>
- Di Salvo V, Gregson W, Atkinson G, Tordoff P, and Drust B (2009). Analysis of High-Intensity Activity in Premier League Soccer. *Int J Sports Med* 30:205-212. <https://doi.org/10.1055/s-0028-1105950>
- Faude O, Schmidt C, and Meyer T (2011). Altitude Adaptation and Team Success during the FIFA World Cup 2010. *J. Exerc. Physiol. Online* 14:41-48.
- Faude, O., Koch, T., & Meyer, T. (2012). Straight sprinting is the most frequent action in goal situations in professional football. *J. Sports Sci.* 30(7), 625-631. <https://doi.org/10.1080/02640414.2012.665940>
- Garvican LA, Hammond K, Varley MC, Gore CJ, Billaut F, and Aughey RJ (2014). Lower running performance and exacerbated fatigue in soccer played at 1600 m. *Int J Sports Physiol Perform* 9:397-404. <https://doi.org/10.1123/ijsp.2012-0375>
- Girard O and Pluim BM (2013). Improving team-sport player's physical performance with altitude training: from beliefs to scientific evidence. *Br J Sports Med* 47:i2-i3. <https://doi.org/10.1136/bjsports-2013-093119>
- Girard O, Amann M, Aughey R, Billaut F, Bishop DJ, Bourdon P, Buchheit M, Chapman R, D'Hooghe M, Garvican-Lewis LA, Gore CJ, Millet GP, Roach GD, Sargent C, Saunders PU, Schmidt W, and Schumacher YO (2013). Position statement-altitude training for improving team-sport players' performance: current knowledge and unresolved issues. *Br J Sports Med* 47:i8-i16. <https://doi.org/10.1136/bjsports-2013-093109>
- Girard O, Brocherie F, and Millet GP (2017). Effects of altitude/hypoxia on single- and multiple-sprint performance: a comprehensive review. *Sports Med* 47:1931-1949. <https://doi.org/10.1007/s40279-017-0733-z>
- Gore CJ, Little SC, Hahn AG, Scroop GC, Norton KI, Bourdon PC, Woolford SM, Buckley JD, Stanef T, Campbell DP, Watson DB, and Emonson DL (1997). Reduced performance of male and female athletes at 5800m altitude. *Eur. J. Appl. Physiol.* 75:136-143. <https://doi.org/10.1007/s004210050138>
- Gore CJ, McSharry PE, Hewitt AJ, and Saunders PU (2008). Preparation for football competition at moderate to high altitude. *Scand J Med Sci Sports* 18:85-95. <https://doi.org/10.1111/j.1600-0838.2008.00836.x>
- Gore CJ, Aughey RJ, Bourdon PC, Garvican-Lewis LA, Soria R, Claros JCJ, Sargent C, Roach GD, Buchheit M, Simpson BM, Hammond K, Kley M, Wachsmuth N, Pepper M, Edwards A, Cuenca D,

- Vidmar T, Spielvogel H, and Schmidt WF (2013). Methods of the international study on soccer at altitude 3600 m (ISA3600). *Br J Sports Med* 47:i80-i85. <https://doi.org/10.1136/bjsports-2013-092770>
- Haugen T and Buchheit M (2015). Sprint Running Performance monitoring: Methodological and Practical Considerations. *Sports Med* 46:641-656. <https://doi.org/10.1007/s40279-015-0446-0>
- Hörzer S, Fuchs C, Gastinger R, Sabo A, Mehnen L, Martinek J, and Reichel M (2010). Simulation of spinning soccer ball trajectories influenced by altitude. *Procedia Eng.* 2:2461-2466. <https://doi.org/10.1016/j.proeng.2010.04.016>
- Levine BD, Stray-Gundersen J, and Mehta RD (2008). Effect of altitude on football performance. *Scand J Med Sci Sports* 18:76-84. <https://doi.org/10.1111/j.1600-0838.2008.00835.x>
- McSharry PE (2007). Effect of altitude on physiological performance: a statistical analysis using results of international football games. *BMJ* 335:1278-1281. <https://doi.org/10.1136/bmj.39393.451516.AD>
- Mureika JR (2006). The effects of temperature, humidity, and barometric pressure on short-sprint race times. *Can J Phys* 84:311-324. <https://doi.org/10.1139/p06-057>
- Nassis GP (2013). Effect of Altitude on Football Performance. *J. Strength Cond. Res.* 27:703-707. <https://doi.org/10.1519/JSC.0b013e31825d999d>
- Povea C, Schmitt L, Brugniaux J, Nicolet G, Richalet J-P, and Fouillot J-P (2005). Effects of Intermittent Hypoxia on Heart Rate Variability during Rest and Exercise. *High Alt. Med. Biol* 6:215-225. <https://doi.org/10.1089/ham.2005.6.215>
- Saavedra García M, Gutiérrez Aguilar Ó, Marques PS, Torres Tobío G, and Romero JJF (2013). Calculating Home Advantage in the First Decade of the 21th Century UEFA Soccer Leagues. *J Hum Kinet* 38:141-150. <https://doi.org/10.2478/hukin-2013-0054>
- Sarmiento, H., Marcelino, R., Anguera, M. T., Campaniço, J., Matos, N., & Leitão, J. C. (2014). Match analysis in football: a systematic review. *J. Sports Sci.*, 32(20), 1831-1843. <https://doi.org/10.1080/02640414.2014.898852>
- Tovar J (2014). Gasping for air: soccer players' passing behavior at high-altitude. *J. Quant. Anal. Sports* 10. <https://doi.org/10.1515/jgas-2014-0035>
- Tucker R, Rauch L, Harley YR, and Noakes T (2004). Impaired exercise performance in the heat is associated with an anticipatory reduction in skeletal muscle recruitment. *Pflugers Arch* 448. <https://doi.org/10.1007/s00424-004-1267-4>

