Altitude Adaptation and Team Success during the FIFA World Cup 2010

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ABSTRACT

Faude O, Schmidt C, Meyer T. Altitude Adaptation and Team Success during the FIFA World Cup 2010. JEPonline 2011;14(4):41-48. The present descriptive analysis aimed at comparing the success of teams living at different altitudes during the World Cup. Altitude of team hotels and stadiums was obtained from Google Earth. Teams were assigned to 3 different categories: sea level (<500 m, N = 7), low altitude (500 to 1,500 m, N = 16), and medium altitude (>1,500 m, N = 9). Match results and FIFA world ranking positions were obtained from www.fifa.com. Median world ranking position was similar in all altitude categories (19 to 22, P = 0.78). When teams played against teams of lower altitude category, winning and losing percentages were 44% (95% CI: 26 to 62%) and 22% (95% CI: 8 to 36%), respectively. Winning percentage of low and medium altitude teams was more than twice that of sea level teams. Teams living at medium altitude showed the best relationship of scored vs. received goals when matches were played in Johannesburg (~1,700 m) with most goals scored during the 2nd half of the match. In conclusion, the choice of accommodation during the World Cup might have influenced team success. When competitions take place at different altitudes, it should be taken into account that altitude acclimatization may give advantage compared to living at sea level.

Key Words: Altitude Acclimatization, Football, Soccer, Match Performance, Hypoxia
INTRODUCTION

Whereas the optimal organization of altitude training to optimize performance at sea level is heavily discussed in the scientific community, the benefit of altitude acclimatization (about 1 to 2 weeks) for competitions at moderate altitudes above 2,000 m is well established (2). For instance, Gore et al. (6) showed that South American teams from moderate to high altitudes (>2000 m, Columbia, Ecuador, Bolivia) have an advantage when playing their home matches against opponents from sea level. Minor impairments in performance or maximal aerobic capacity, however, may already become apparent at altitudes above 500 m. Gore et al. (5) reported approximately 7% reduction in maximal oxygen uptake (VO$_2$ max) in highly trained cyclists 580 m above sea level. Similarly, Wehrlein and Hallen (12) showed a linear decrease in VO$_2$ max with increasing altitude (~7% reduction per 1000 m).

Playing football is characterized by about 10 to 12 km running and walking distance covered by each player with an average work rate of 70 to 75% VO$_2$ max as well as frequent changes of activities with high-intensity bouts on average every 70 sec (11). Due to the high frequency of short-term maximal running activity VO$_2$ max has been considered a major determinant of football performance (1,7). Thus, the exposition of players to low altitudes (500 to 2,000 m) might have detrimental effects on performance in match play. Weston et al. (13) showed that even after 47 hr of acclimatization to 1,700 m above sea level performance was not entirely restored. Therefore, Bärtsch et al. (2) recommended 3 to 5 days of acclimatization when performing at an altitude above 1,500 m.

During the FIFA World Cup 2010 in South Africa matches were played from sea level (e.g., Cape Town, Port Elizabeth, Durban) up to an altitude of about 1,700 m (Johannesburg). Thus, for sports medical team advisors it was a challenge to choose an appropriate team accommodation to cope with the possibility of consecutive matches conducted at sea level and in 1,700 m altitude. Several teams decided to live at low altitudes (>500 m); whereas, others stayed at sea level during the World Cup. The present descriptive analysis aimed at comparing the success of teams living at different levels of altitude during the FIFA World Championship 2010.

METHODS

Information about team hotels were taken from the internet. This information was verified by at least two different websites. Exact addresses for all hotels were obtained from the hotels’ own websites. Using these addresses Google Earth (Version 5.2.1) was searched for the hotels. Altitude above sea level is automatically displayed by the program. Similarly, altitude for all official stadiums was obtained via Google Earth. Team accommodation and match location were assigned to one of three altitude categories (2): Sea Level (SL, <500 m), Low Altitude (LA, 500 to 1,500 m), and Medium Altitude (MA, >1500 m). The MA category was chosen, because Bärtsch et al. (2) recommended a short acclimatization period of 3 to 5 days when competing above 1,500 m.

Match results as well as FIFA world ranking positions (WRP) prior to the start of the tournament were obtained from FIFA’s official website (http://de.fifa.com/worldfootball/ranking/lastranking/gender=m/fullranking.html#confederation=0&rank=193; status: 26th of May 2010). FIFA world ranking position is based on an algorithm which includes the number, the results and the importance of matches played during the last 8 yrs, the strength of the opponent and of the own continental confederation, the number of scored and received goals, and whether the match was played at home or away (http://de.fifa.com/worldfootball/ranking/procedure/men.html).
In addition, information about the preparation period prior to the World Cup with particular reference to training camps above 1,500 m was obtained from newspapers and the internet (traceable information for 28 out of 32 teams).

Statistical Analyses
Data for altitude of the accommodation and world ranking position were not normally distributed. Therefore, they are presented as medians with upper and lower quartiles. WRP for the different altitude categories was compared using a Kruskal-Wallis-ANOVA. Winning percentages ((number of won matches/total number of matches) * 100%) are provided together with corresponding 95% confidence intervals (CI), which were calculated according to the following equation: 95% CI = (1.96 * \(\sqrt{p \times (1-p)/N}\)) * 100% with \(p = \text{number of won matches/total number of matches}\).

RESULTS
Although average WRP was similar in all groups (\(P = 0.78\)), most teams living at sea level were eliminated after the preliminary round (Table 1). In addition, all quarterfinalists had their base camp at an altitude above 1,100 m. Teams arrived at their base camp on average 7 days (range = 5 to 19) prior to their first match with no differences between the 3 categories (\(P = 0.54\)).

Table 1. Characteristics of teams living at different altitudes during the FIFA World Cup 2010. WRP = FIFA world ranking position prior to the start of the tournament. Data for altitude and WRP are given as median with lower and upper quartiles.

<table>
<thead>
<tr>
<th>Altitude</th>
<th>N</th>
<th>Altitude (m)</th>
<th>WRP</th>
<th>Out After First Round</th>
<th>Out After Round of 16</th>
<th>Out After Quarterfinals</th>
<th>Semifinals</th>
<th>Matches Played (Won/Drawn/Lost)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medium (&gt;1,500 m)</td>
<td>9</td>
<td>1,620</td>
<td>22</td>
<td>5</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>35 (14/10/11)</td>
</tr>
<tr>
<td>Low (500 to 1,500 m)</td>
<td>16</td>
<td>1,358</td>
<td>19</td>
<td>5</td>
<td>5</td>
<td>3</td>
<td>3</td>
<td>71 (28/22/21)</td>
</tr>
<tr>
<td>Sea Level (&lt;500 m)</td>
<td>7</td>
<td>67</td>
<td>21</td>
<td>6</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>22 (4/4/14)</td>
</tr>
</tbody>
</table>

When teams played against a team of a lower altitude category (\(N = 36\) matches), the winning percentage was 44% (95% CI = 26 to 62%) while only 22% (95% CI = 8 to 36%) of those matches were lost. In addition, Low Altitude (LA) and Medium Altitude (MA) showed a winning percentage more than twice that of Sea Level (SL) (refer to Figure 1). Table 2 gives an overview of goals scored and received during the tournament with reference to the altitude of team accommodation as well as the altitude of match location. LA and MA showed a better relation of scored versus received goals compared to SL. This was especially true for MA when matches (\(N = 9\)) were played in Johannesburg.
(~1,700 m, 2 stadiums). In addition, teams which lived above 1,500 m scored most goals during the second half of the matches; whereas, this was more equally distributed in all other teams.

Table 2. Overview of goals scored and received during the FIFA World Cup 2010 with reference to the altitude of accommodation and the site where the matches were played. Data presented as goals per match (absolute values in parentheses).

<table>
<thead>
<tr>
<th>Accommodation at...</th>
<th>Goals per Match</th>
<th>Total</th>
<th>1st Half</th>
<th>2nd Half</th>
<th>Matched Played</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>&lt; 500 m</td>
<td>500-1,500 m</td>
<td>&gt; 1,500 m</td>
</tr>
<tr>
<td>Medium Altitude</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(&gt;1,500 m)</td>
<td>Scored</td>
<td>1.2</td>
<td>0.3</td>
<td>0.8</td>
<td>1.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(41/35)</td>
<td>(12/35)</td>
<td>(29/35)</td>
<td>(21/16)</td>
</tr>
<tr>
<td></td>
<td>Received</td>
<td>1.0</td>
<td>0.3</td>
<td>0.7</td>
<td>1.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(36/35)</td>
<td>(10/35)</td>
<td>(26/35)</td>
<td>(17/16)</td>
</tr>
<tr>
<td>Low Altitude</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(500 to 1,500 m)</td>
<td>Scored</td>
<td>1.3</td>
<td>0.5</td>
<td>0.7</td>
<td>1.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(87/71)</td>
<td>(39/71)</td>
<td>(48/71)</td>
<td>(29/24)</td>
</tr>
<tr>
<td></td>
<td>Received</td>
<td>1.1</td>
<td>0.5</td>
<td>0.6</td>
<td>1.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(78/71)</td>
<td>(36/71)</td>
<td>(42/71)</td>
<td>(28/24)</td>
</tr>
<tr>
<td>Sea Level</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(&lt;500 m)</td>
<td>Scored</td>
<td>0.7</td>
<td>0.4</td>
<td>0.3</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(15/22)</td>
<td>(8/22)</td>
<td>(7.22)</td>
<td>(3/6)</td>
</tr>
<tr>
<td></td>
<td>Received</td>
<td>1.3</td>
<td>0.6</td>
<td>0.7</td>
<td>1.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(29/22)</td>
<td>(13/22)</td>
<td>(16/22)</td>
<td>(7/6)</td>
</tr>
</tbody>
</table>

Seven teams were in training camps above 1,500 m prior to the World Cup (SL: N = 3, LA: N = 2, MA: N = 2) and one team (LA) used hypoxic chambers during the preparation period. Five of those teams retired after the preliminary round, two after the round of 16, and one team reached the quarterfinals.

**DISCUSSION**

The results of this descriptive study reveal that performance during the FIFA World Cup 2010 was better in teams that lived at altitude (between 950 m and 1,700 m) compared to the teams that decided to take their base camp near sea level. This finding was true for winning percentage as well as for the number of scored goals.

During the World Cup, sea level based teams only won those matches at altitudes between 1,170 m and 1,390 m (N = 4) when their opponent also lived near sea level. In addition, MA teams scored more goals, particularly in the second half and when playing in Johannesburg (stadiums with highest altitude). Furthermore, when playing against an opponent based at a lower altitude level the chance to win the match was doubled. Thus, staying at altitude seems to give an advantage during a tournament involving matches at altitude compared to living at sea level.
It is well established that teams living at altitude have an advantage compared to sea level teams when competitions take place in altitude (6,9). These effects might be caused by two different mechanisms: (1) a physiological; and (2) a physical effect of altitude exposure (9).

Figure 1. Winning percentage of teams living at different altitudes during the FIFA World Cup 2010. Data as relative frequencies with 95% confidence intervals.

With increasing altitude there is a gradual impairment in VO$_2$ max by about 0.5 to 1% per 100 m beginning at about 600 to 800 m in trained athletes with a slightly greater decrease in sport specific endurance performance (9). This might have led to a decrement in endurance capacity at an altitude of about 1,700 m (Johannesburg) of up to 10%. Similarly, Levine et al. (9) estimated that repeated sprint performance might be impaired by about 2.5% per 1,000 m altitude difference, particularly when work-to-rest ratio is less than 1:3 as it might sometimes occur in highly intensive football match periods. As VO$_2$ max, endurance capacity, and repeated sprint ability have been shown to be important prerequisites of football performance (8,11), such impairments may have detrimental effects on match performance. However, it is likely that the altitude associated impairment in physiological performance can be reversed by timely acclimatization. In fact, it has recently been recommended that even for competitions at an altitude of about 1,700 m several days (3 to 5 days) of acclimatization might be beneficial (e.g., for Johannesburg) (2,6).
An increase in total hemoglobin mass is often regarded as the most important adaptation to altitude training in elite athletes if a minimum “hypoxic dose” (more than 3 weeks in an altitude above 2,000 m) is reached (4). Interestingly, a recently published study analyzed the effects of repetitive periods (i.e., 2 times for about 3 weeks) of living and training at altitudes between 1,300 m and 1,650 m on erythropoiesis in 8 elite runners (3). After the first 20-days in the training camp in South Africa (1,300 m above sea level) total hemoglobin mass was augmented by 4% on average ($P = 0.07$). In addition, erythropoietin and the soluble transferrin receptor were significantly increased after 10 and 17 days of altitude exposure. During the training camp, the athletes performed endurance, interval, sprint, and strength training.

During the FIFA World Cup, the teams arrived at their base camps on average 7 days prior to their first match and about 17 to 18 days prior to the last match of the preliminary round. Taking these considerations into account, it might be speculated that teams living at altitude may also have had an advantage when playing at sea level. This may have contributed to the higher winning percentage of altitude teams which was also observed for sea level matches. A further effect on performance might result from the decreased air density at altitude which is reduced by about 3% per 305 m (9). Thus, air density and, consequently drag and lift forces effecting ball flight, were about 17% lower in Johannesburg compared to sea level (e.g., Port Elizabeth). This factor also has an influence on sprint times, which are improved with increasing altitude (9,10).

The athlete’s prediction and anticipation of the flight of the ball might be impaired when playing at altitude. It can be hypothesized that they will adapt to the changes in ball behavior when practicing for some period of time at altitude. However, there are no convincing scientific data on the adaptability to this problem yet (9). An advantage from this fact for SL teams when playing at sea level as compared to LA and MA teams cannot be ruled out, although the teams with higher base camps were also used to playing at sea level from their home countries’ circumstances. Thus, this effect is likely to be of minor importance compared to the physiological effects of altitude adaptation.

**Limitations of this approach**

The present descriptive study suffers from several methodological limitations. First of all, the low number of teams in the sea level group and, particularly, the low number of matches played above 1,500 m of these teams ($N = 2$) should be considered as critical. Thus, a descriptive statistical approach was appropriate and the results have to be interpreted with care.

Furthermore, there are several other confounding factors. For instance, previous altitude exposure of players or teams or training camps with different contents as well as the period of time the teams were able to prepare for the tournament might have influenced the present results. Although the preparation period was taken into account, such confounding cannot be completely ruled out.

A further limitation might be seen in the use of FIFA world ranking position to classify playing ability of the teams. However, this ranking is based on objective and traceable criteria and, therefore, may enable the most reasonable classification that can be achieved.

**CONCLUSIONS**

From the results of the present study, it is concluded that the choice of accommodation during the FIFA World Cup 2010 might have influenced team success. Thus, when matches during a tournament will be played at different altitudes, it should be considered that timely acclimatization to
altitude may give advantage compared to living at sea level. Also, given the mentioned methodological limitations, these results have to be interpreted with care. Nevertheless, it should be considered that this study includes the most outstanding football teams of the world. Therefore, the present descriptive analysis gives direction for future research in this area to identify optimal preparation strategies for competitions at low to moderate altitudes in high level athletes.

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